

**DEPARTMENT OF NATIONAL DEFENCE
CANADA**



OPERATIONAL RESEARCH DIVISION

ORD REPORT R9903

THE CANADIAN MARITIME FORCES 2015 STUDY

**PHASE II:
ANALYSIS OF MARITIME FORCE STRUCTURE
ALTERNATIVES USING THE FLEETSIM MODEL**

by

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July 1999

OTTAWA, CANADA



**National
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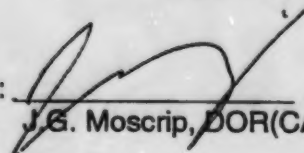
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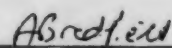
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OTTAWA, CANADA

JULY, 1999

ABSTRACT

This report presents a description of the FLEETSIM model and a number of results which have been produced using this model to evaluate future maritime force structure options. The FLEETSIM model is a resource scheduling simulation model where different types of ships and aircraft are scheduled to perform a comprehensive selection of routine and unforeseen maritime force generation and force employment activities. This model was used to investigate the ability of different future maritime force structures to respond to Canada's national and international defence requirements. The results of this effort created an empirical and logical process that links national policy directives to maritime force structure requirements. Many possible force structures were examined and compared to the current (1998) Maritime force structure.

RÉSUMÉ

Le présent rapport de projet décrit le modèle FLEETSIM et plusieurs des résultats obtenus en utilisant ce modèle pour évaluer les options de structure future des forces maritimes. Le modèle FLEETSIM est un modèle de simulation d'ordonnancement des ressources dans lequel divers types de navires et d'aéronefs sont programmés pour exécuter une sélection complète d'activités de formation et d'utilisation des forces maritimes selon des scénarios prévisibles et imprévisibles. Le modèle a servi à évaluer l'aptitude de différentes structures futures des forces maritimes à répondre aux besoins du Canada en matière de défense nationale et internationale. Il en est résulté un processus expérimental logique qui établit un lien entre les directives en matière de politiques nationales et les besoins de structure des forces maritimes. De nombreuses possibilités de structures des forces ont été étudiées et comparées à celle des forces maritimes actuelles (1998).

EXECUTIVE SUMMARY

In 1995 the staff of the Director of Maritime Strategy (DMarStrat)¹ began study of the future requirements and force structure needs of Canada's Maritime Forces. Under the lead of DMarStrat, a strategic analysis of Canada's maritime defence needs was conducted. Published under the title: "Adjusting Course: A Naval Strategy For Canada," this work has been followed by a two phased Operational Research Division (ORD) project known as the Canadian Maritime Forces in 2015 (CMF 2015) Study.

The first phase of the CMF 2015 Study was 'qualitative' in nature. It involved a survey of maritime warfare experts who were asked to identify the strengths and weaknesses of Canada's current maritime combat capability. This effort provided a number of relevant short term observations and conclusions which have been reported on extensively in ORD Project Report 9602, "The Canadian Maritime Forces 2015 Study Phase I: Maritime Experts Survey Final Report."

This, the second phase, addresses the 'quantitative' issue of how well different force structure alternatives would meet a realistic set of force generation and force employment taskings over a given period of time. This issue has been approached through the development of a detailed simulation model known as FLEETSIM. FLEETSIM schedules a variety of maritime force assets and assesses the force structure based on its ability to provide the appropriate assets to the projected force employment taskings over an extended period of time. In this report, the FLEETSIM model is introduced, and some of the results which have been obtained from its use so far are presented.

THE FLEETSIM MODEL

FLEETSIM is a fleet scheduling simulation model that provides information to the user on how well a given force structure might respond to various maritime taskings. It simulates these taskings on a day by day basis for periods of multiple years as set by the user. The fleet assets are the ships and aircraft that could be employed in a maritime defence role. The taskings encompass a full range of operational taskings, including force generation tasks,

¹ The Director of Maritime Strategy is part of the Chief of Maritime Staff in NDHQ, in 1995 it was known as the Director General of Maritime Development.

such as maintenance periods, trials, and training exercises, as well as force employment taskings, such as filling standing alliance commitments and responding to national and international contingencies that may arise. These contingency operations are represented by five scenarios which were developed for the CMF 2015 Study and predate the Canadian Forces' (CF's) Directorate of Defence Analysis sponsored set of 11 scenarios. Briefly, Scenario 1 is a smuggler interdiction scenario; Scenario 2 is an ocean resource dispute scenario; Scenario 3 is an UN embargo scenario; Scenario 4 is a protection of shipping scenario; and Scenario 5 is an international power projection scenario.

The FLEETSIM model begins with three key sets of inputs:

- a) the force structure data set - the different force structures that are to be studied;
- b) the activity rate data set - the periodicity and frequency of each tasking; and,
- c) the Task Based Grade Tables - used to grade the level of success achieved by the model's efforts to schedule the desired resources to specific tasks.

When these inputs are combined and manipulated by the model's scheduling logic the initial product is a five year fleet schedule that is very similar to an operations schedule that might be employed to schedule Canada's Maritime Forces. Since the frequency and duration of the taskings vary from year to year, no one year's operations schedule is identical to another's. FLEETSIM takes this random variation of frequency and task duration into account and after many runs of the model (hundreds, and even thousands, if desired) it builds a picture of what an 'average' schedule is like. The final step is to record various results from FLEETSIM in the course of each run and to use them to measure and compare the success of a given force structure with other force structures.

Two aggregate measures of effectiveness that are employed in this report are a force structure's AS(C) score and values for the Average Sea Days (AveSD) per year per class of ship. The AS(C) score is the average probability that a given force structure will be able to provide an 'Adequate' grade response to the five CMF 2015 Scenarios. An 'Adequate' grade is one of the seven grades that were used in the Task Based Grade Tables. For Scenario 1, which is at a relatively low level in terms of intensity and resource utilisation, the 'Adequate' grade included combinations of assets which were less than those required to make up a Canadian Task Group (CTG). In the case of Scenarios 2-5, an 'Adequate' grade response

was, at a minimum, a combination of assets that equalled a CTG or more precisely four naval combatants, a support ship, and associated maritime air support as articulated in the 1994 Defence White Paper and the 1997 Defence Planning Guide. The second measure of performance, which is reported upon in this report, is the AveSD, which is the average number of sea days per year per class of ship for each force structure².

RESULTS OBTAINED USING FLEETSIM

In this report the results of FLEETSIM runs using a total of 17 different force structures were compared and presented. These 17 different force structures are, for the most part, variations on a baseline force structure, which closely mirrors the CF reality of 1997 and consists of the various platforms listed in Table ES-1. The numbers of seagoing platforms represent the total number of those units. However, the numbers of aircraft represent estimates of the number of aircraft that, on average on any given day, are on the flight line, or in other words the number of aircraft that are not in maintenance or dedicated training and, therefore, are available for employment.

TABLE ES-1

TABLE OF THE COMPONENTS OF THE BASELINE FORCE STRUCTURE

PLATFORM	NUMBER	PLATFORM	NUMBER
CPF	12	MCDV	12
CADRE	4	SSK	4
AOR	3	MH	20
MRSV(basic)	0	MPA	16
MRSV(loaded)	0	CF-18	30

From the 17 different force structures, three subsets of three or four different force structures, which differed only by the number of one type of platform, were studied in greater detail in terms of activity levels and readiness issues. The first is a group of three force structures that included the baseline force structure plus two other force structures with alternatively two and four Auxiliary Oiler Replenishment (AOR) type platforms.

² In the Executive Summary, AveSD results are mentioned only when they are salient and relevant. They are discussed and reported upon in greater detail in the body of the report.

These three force structures were studied using FLEETSIM under different levels of demand where demand refers to the frequency and degree of concurrency that is assigned to the five CMF 2015 Scenarios. They were also studied under two different readiness assumptions³. Initially, an 'Adequate' grade was achieved only if all the units that could be assigned were at High Readiness (HR). Subsequently, this was relaxed so that an 'Adequate' grade was achieved if either HR or at Normal Readiness (NR) units were assigned. Figure ES-1 is a graph that summarises the FLEETSIM results from these different variations. For ease of comparison, in this and all subsequent graphs, each bar in the graph which corresponds to the baseline force structure has been coloured dark yellow. The terms Lo, Norm and Hi, refer to the level of demand and correspond to lower, normal and higher demand rates, respectively. As well, the yellow portion of each bar represents the AS(C) score value for task groups in which all units must be at HR in order to be graded 'Adequate'. The blue portion of the graph represents the additional responsiveness that is obtained at the 'Adequate' grade when NR units are accepted without penalty.

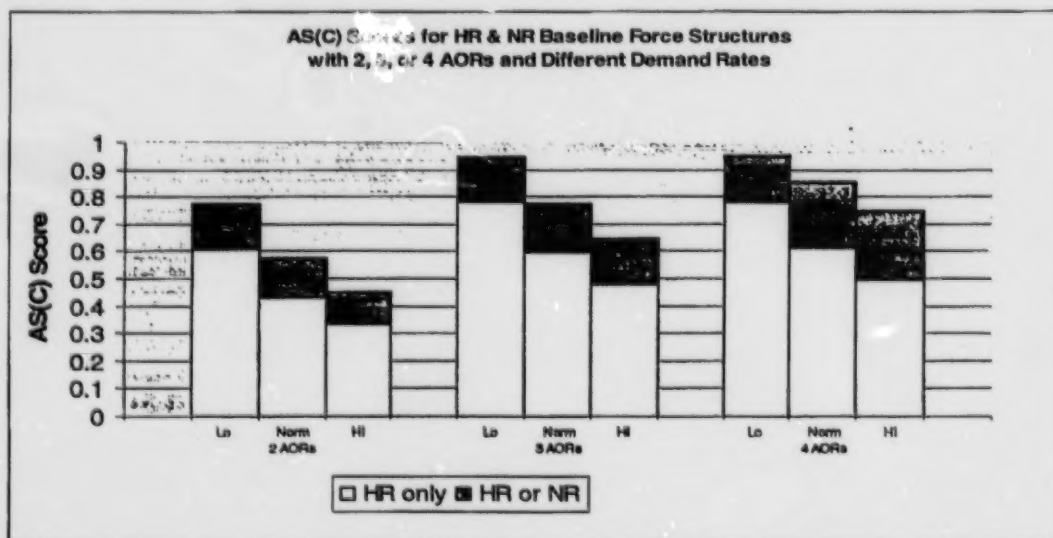


Figure ES-1: AS(C) Score-Force Structures with 2, 3, or 4 AORs & Different Demand Rates

³ Readiness refers to how well prepared a unit is to complete an operational mission. At the time of this report the CF employed the concepts of High, Normal, and Extended Readiness. In terms of training, manning, logistics, and material readiness a unit that was at HR was expected to be ready to deploy to an operational mission in either 10 or 30 days. A unit at Normal Readiness had lower levels of training, manning, logistics, and material readiness and thus was only expected to be ready to deploy to an operational mission in 90 days.

As one would anticipate, this figure shows that lower levels of demand have a positive effect and higher levels of demand have a negative effect on the responsiveness of the three force structures under consideration. As well, there is little difference between the force structures with three or four AORs, but there is a significant decline in responsiveness in the force structure with two AORS. Finally, accepting NR units (which could also be thought of as drawing from a force structure where all available units are assumed to be at HR) improves responsiveness across the board. The conclusion that can be drawn from this is that baseline force structures with three or four AORs are of sufficient resource depth to meet any one scenario that may arise, but shows signs of being unable to respond reliably when asked to provide forces to more than one major scenario at the same time.

Similar excursions with force structures which had 0, 2 and 4 Command/Control and Air Defence (CADRE) platforms and 6, 8, 10 and 12 CPF platforms were studied, applying the assumptions of different demand levels and alternatively rejecting and accepting NR units for operational deployments. The graphs containing these results are presented in Figures ES-2 and ES-3.

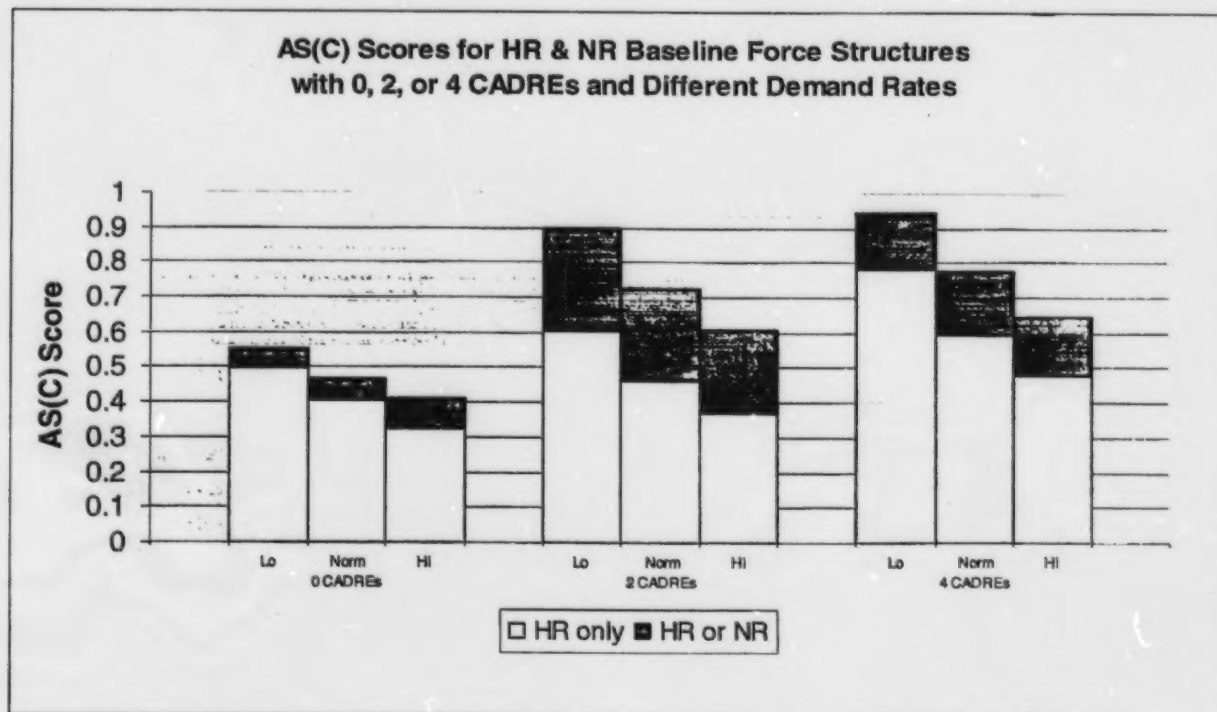


Figure ES-2: AS(C) Score-Force Structures of 0, 2, or 4 CADREs & Different Demand Rates

Figure ES-2 again shows the positive and negative impact that increasing or decreasing the demand rate has on the overall responsiveness. In terms of the impact that decreasing the number of CADRE ships from 4 to 2 or 0 has on responsiveness, this graph shows a steady decline in responsiveness in all cases when only HR units are deemed acceptable. Although this would likely raise the risk of mission failure, accepting NR units without penalty results in a much less dramatic decline in responsiveness between force structures with 4 or 2 CADREs. Overall, explorations with three variations of the baseline force structure have demonstrated that, under the current readiness constraints, force structures with 0 CADREs and with only 2 CADREs are notably less responsive than the FLEETSIM baseline force structure with 4 CADREs.

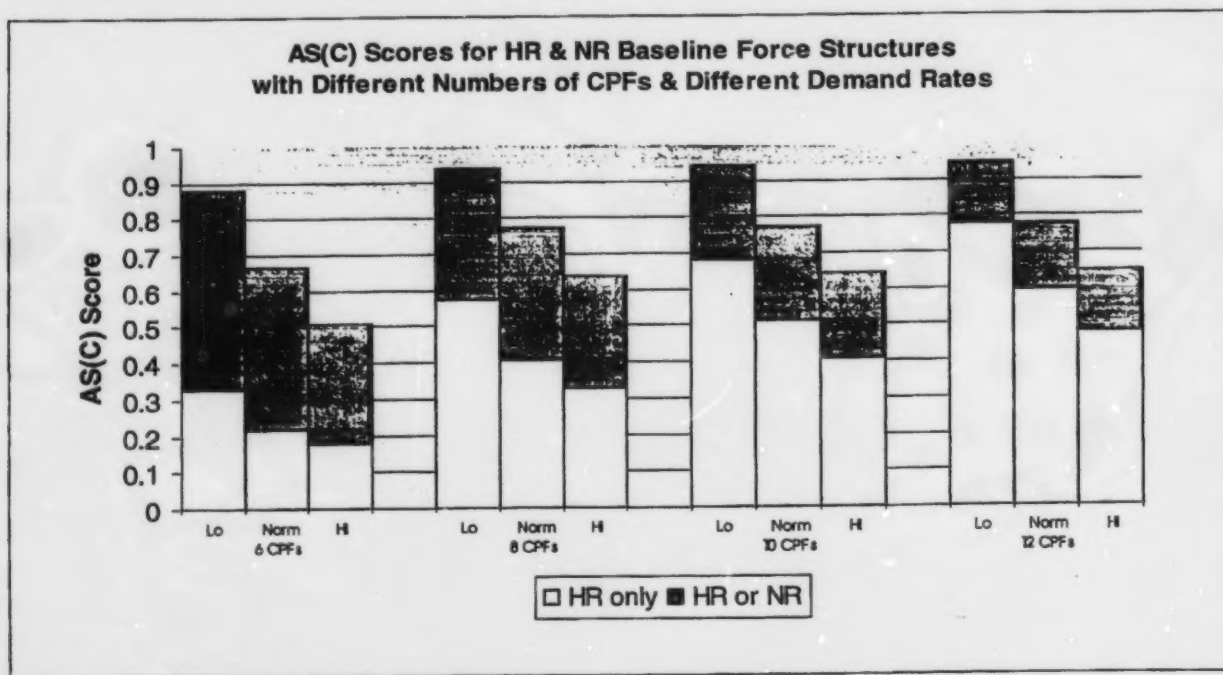


Fig ES-3: AS(C) score for Force Structures with Different Numbers of CPFs & Different Demand Rates

Figure ES-3 shows the positive and negative impact that increasing or decreasing the demand rate has on the overall responsiveness. When only HR units are deemed acceptable decreasing the number of CPF ships from 12 through to 8 results in a steady decline in responsiveness. If NR units are accepted without penalty, decreasing the number of CPFs

corresponds with an increase in the utilisation rates (as measured by the AveSD per class,) but there is no effect on responsiveness until the number of CPFs is reduced to less than 8. Also of note is that in comparison to the results in the previous two graphs the removal of two CPFs from the baseline force structure has a much more limited impact than the removal of either 2 CADREs or one AOR. In conclusion, when NR units are scheduled for operational deployments without penalty, the responsiveness of force structures with 8 or more CPFs is not limited by the availability of CPFs.

After this detailed analysis of similar force structure options, a larger group of possible future force structures was explored using FLEETSIM. A total of seventeen force structures including the eight different force structures discussed above and an additional nine force structures were run. These different force structures were grouped in four sub-groups based on their estimated capital costs over a twenty year planning cycle and the results are presented in Figure ES-4 below.

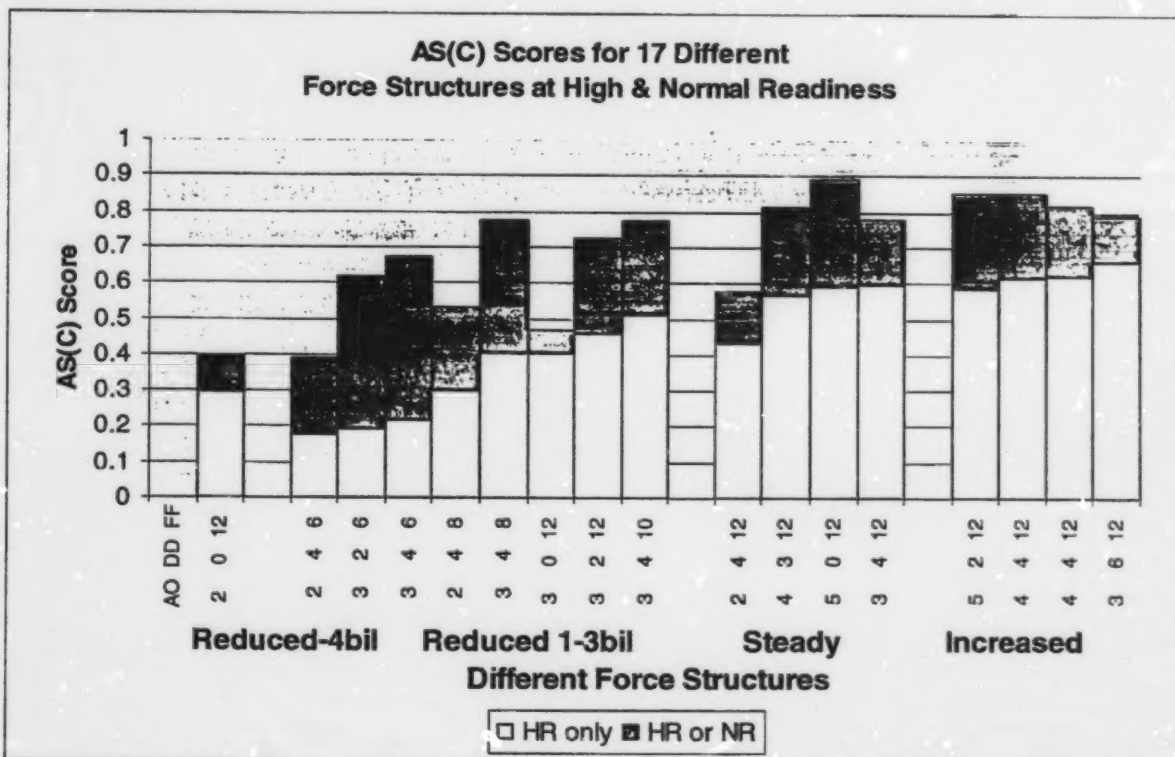


Fig ES-4: AS(C) score for 17 Different Force Structures at HR and NR

In general, these results demonstrate that there are a number of reasonably effective force structures which could be used to fulfil Canada's maritime force commitments into the next century. Interestingly, however, one significant observation that follows from a study of these results is that increasing the capital budget does not gain a corresponding increase in overall responsiveness. In other words, the force structures which are grouped in the 'Increase' sub group do not perform much better than some of the 'Steady Funding' group. In the other direction, when capital budget funding is reduced, the results show an immediate and notable decrease in responsiveness for all the force structures studied.

CONCLUSIONS

The CMF 2015 Study has achieved two significant milestones: it has created a methodology and a model that can be used to study maritime force structure questions, and it has employed this model to gain some insight into the current and future force structure needs of the Canadian Forces.

In terms of model development and methodology, the authors conclude that:

- a. in the efforts to create an empirical and logical process that is able to link national policy directives to maritime force structure requirements, the development and employment of the FLEETSIM model is a significant achievement; and,
- b. the results from the use of the FLEETSIM model can be used to show which force structures would better serve Canada's defence needs in comparison to other force structures in a relative sense.

In terms of the results obtained from the study of a number of different force structures using FLEETSIM, the authors conclude that:

- a. AORs – force structures with less than three AORs are notably less responsive than force structures with three or more AORs;
- b. CADREs - force structures with zero or two CADREs are seriously affected in their abilities to respond to the five CMF 2015 Scenarios, and overall are notably less responsive than force structures with four or more CADREs;
- c. CPFs – a reduction in the number of CPFs by two has much less impact than the loss of two CADREs or one AOR. Force structures with less than eight CPFs show a notable decline in responsiveness;
- d. Increasing the Capital Budget - spending significantly more money from the capital budget does not translate into a notable improvement in responsiveness; and,
- e. Decreasing the Capital Budget - spending significantly less money from the capital budget translates into notably poorer responsiveness.

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LIST OF TERMS & ABBREVIATIONS

AAW	Anti-Air Warfare
AORs	Auxiliary Oiler Replenishment ship
AS(C) score	Aggregate probability of obtaining a 'C' grade for all five scenarios
AS(x)	Aggregate probability of obtaining a grade of x for all five scenarios
AsuW	Anti-Surface Warfare
ASW	Anti-Submarine Warfare
AveSD	Average Sea Days per class per year
CADRE	Command/Control and Air Defence Replacement Ships
CF	Canadian Forces
CF 18	Canadian Forces Hornet jet fighter
CMF 2015	Canadian Maritime Forces in the year 2015
CPF	Canadian Patrol Frigate
CTG	Canadian Task Group
DMarStrat	Director of Maritime Strategy
DPG	Defence Planning Guide
FLEETSIM	Fleet Simulation
Force Employment	Use of one or more military units in support of one of the CF's many missions
Force Generation	Training, preparation and maintenance of a unit of the CF so that it is being readied or ready for use in a Force Employment role
HR	High Readiness
MCDV	Maritime Coastal Defence Vessels
MH	Maritime Helicopter
MPA	Maritime Patrol Aircraft
MRSV(basic)	Multi-Role Support Vessels – basic
MRSV(loaded)	Multi-Role Support Vessels – loaded
MTA	Measure of Task Availability
NR	Normal Readiness
RCMP	Royal Canadian Mounted Police
RIMPAC	Biennial Pacific Rim allied naval exercise
SatRecc	Satellite Reconnaissance
SSK	Conventionally powered submarine with ASW capability
TG	Task Group

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PHASE II:

ANALYSIS OF MARITIME FORCE STRUCTURE
ALTERNATIVES USING THE FLEETSIM MODEL

I. INTRODUCTION

1. In 1995 the staff of the Director of Maritime Strategy (DMarStrat)¹ initiated a study of the future long term requirements and force structure needs of Canada's Maritime Forces. Under the lead of DMarStrat, a strategic analysis of Canada's maritime defence needs was conducted and published under the title: "Adjusting Course: A Naval Strategy For Canada," (Reference [1]). This work has been followed by a two phased Operational Research Division (ORD) project known as the Canadian Maritime Forces in 2015 (CMF 2015) Study.

2. The first phase of the CMF 2015 Study was 'qualitative' in nature. It involved a survey of maritime warfare experts who were asked to identify the strengths and weaknesses of Canada's current maritime combat capability. This effort provided a number of relevant short term observations and conclusions which have been reported on extensively in References [2 - 6].

3. The second phase addresses the 'quantitative' issue of how well different force structure alternatives would meet a realistic set of force generation and force employment taskings over a given period of time. This issue has been approached through the development of a detailed simulation model known as FLEETSIM. FLEETSIM schedules a variety of maritime force assets and assesses the force structure based on its ability to provide the appropriate assets to the projected force employment taskings over an extended period of time. In this report, we present the FLEETSIM model, discuss its assumptions and limitations, and report on the results, which have been obtained from its use so far.

¹ The Director of Maritime Strategy is part of the Chief of Maritime Staff in NDHQ, in 1995 it was known as the Director General of Maritime Development.

II. METHODOLOGY

4. In terms of the methodology that underlies the FLEETSIM model, there are five areas of discussion. These areas are:

- a. a description of the model;
- b. notes on the data which is input into the model;
- c. observations on the logic and internal rule sets;
- d. observations on the model's limitations; and,
- e. a presentation on how the model has been employed.

Each of these is discussed in turn in the following sections.

MODEL DESCRIPTION – AN OVERVIEW

5. FLEETSIM is a fleet scheduling simulation model that has been written in the C++ language and that provides information to the user on how well a particular force structure could be assigned to various maritime taskings. It simulates these taskings on a day by day basis for multi-year periods as set by the user. The fleet assets considered are the major ships and aircraft that could be employed in a maritime defence role. The taskings that are included in the simulation encompass the full range of operational taskings from force generation tasks such as maintenance periods, trials, and training exercises through to force employment taskings such as filling standing alliance commitments and responding to national and international contingencies that may arise.

6. The result is a fleet schedule that is very similar to an operations schedule that might be employed to schedule Canada's Maritime Forces. Since the frequency and duration of the taskings vary from year to year, no one year's operations schedule is identical to another's. FLEETSIM takes this random variation of frequency and task duration into account. Thus, after many runs of the model (hundreds, and even thousands, if desired) it is possible to build up a picture of what an 'average' schedule is like.

7. To begin with, the user must decide on the composition of the different force structures that are of interest to the study and combine them into a force structure data set. The user must then gather information about the future taskings, and information about what types and quantities of platform could be assigned to deal with these taskings. For example, a fleet scheduler could assign a single Maritime Patrol Aircraft to a "Persian Gulf" type scenario, or could assign an entire task group. This information is collectively called the activity rate data set.

8. The scheduling algorithm in FLEETSIM will initially assign fleet resources to a range of foreseeable peacetime taskings. Peacetime taskings include training, fleet maintenance, trials, Standing Naval Force Atlantic/Mediterranean commitments, Other Government Department taskings such as support to the RCMP and Fisheries Patrols, and so on. Based on insights gained from the fleet activity study, Reference [7], on current policy guidelines, and on expert opinion, each platform in the fleet is assigned to these various peacetime taskings in a manner that attempts to mimic the way the CF currently schedules its fleet resources. Information about the expected duration, and expected frequency of occurrence of a tasking within the scheduling period is also input into the model. As well, FLEETSIM must deal with the scheduling of resources to respond to unpredicted contingencies.

9. In the FLEETSIM simulation these unpredicted operational taskings are represented by random occurrences of the five CMF 2015 Scenarios. The study team has developed and used these five force employment scenarios to situate the employment of Canada's Maritime Forces in a post Cold War context. The five scenarios are described in detail in Annex A of Reference [6]. Briefly they are:

- a. Scenario 1 - a smuggler interdiction scenario involving detection, tracking and interception of a smuggling operation in or near Canada's national waters;
- b. Scenario 2 - an ocean resource dispute scenario calling for the protection of a national resource in international or disputed waters;
- c. Scenario 3 - a UN sanctioned embargo operation involving surveillance and boarding and search operations in support of an economic embargo;
- d. Scenario 4 - an international protection of shipping scenarios involving efforts to provide safe passage of shipping through potentially hostile or hostile waters; and,

- e. Scenario 5 - a support to forces ashore scenario, involving the application of force to achieve the aims of a UN chapter 7 sanctioned Joint Warfare mission.

Although these five scenarios pre-date the eleven CF-wide scenarios developed by the Director General Strategic Planning (Reference [8]), the CMF 2015 Scenarios are not inconsistent with, and are easily transferable to these department level scenarios.

10. FLEETSIM randomly generates the frequency and duration of the scenarios and notifies the scheduler logic that the fleet resources must be tasked or re-tasked to meet these exigencies. The schedule is changed, as required, to meet the new tasking's requirements. For example, if a frigate must be re-tasked from a surveillance mission the program will attempt to reschedule the surveillance mission with similar assets. If rescheduling is impossible, or the type of asset that is to be assigned to the surveillance mission is inferior to that originally tasked, that information is recorded for later analysis.

11. Canada has a two-coast maritime fleet, and that reality is simulated in the logic of the model. There are assets that are allocated to one coast or the other, and some that, if necessary, can be transferred from one coast to the other. There are tasks that can only be conducted with the assets from one coast or the other, and tasks that can draw upon assets from either coast (e.g., a multinational commitment). Once the fleet has been assigned to all the various unforeseen taskings, the program records how well the fleet coped: that is, how well did this particular force structure meet the demands that were placed upon it?

12. This leads to another of the key inputs into FLEETSIM, the Task Based Grade Tables. A Task Based Grade Table is a matrix of the possible types and quantities of assets that could be deployed to a given tasking. These different asset mixes are ranged on a descending scale and grouped by grades ranging from A to F. In some cases, specifically Scenarios 2-5, the readiness of the units is an issue². The model reasons that since these are potentially medium to high level of conflict scenarios, then it would be preferable to select assets which are at High Readiness (HR). If it can obtain all the desired assets and they are all at HR then it will be scored the appropriate grade. If all the desired assets are available

² Readiness refers to how well prepared a unit is to complete an operational mission. At the time of this report the CF employed the concepts of High, Normal, and Extended Readiness. In terms of training, manning, logistics, and material readiness a unit that was at HR was expected to be ready to deploy to an operational mission in either 10 or 30 days. A unit at Normal Readiness had lower levels of training, manning, logistics, and material readiness and thus was only expected to be ready to deploy to an operational mission in 90 days.

but some of them are only at Normal Readiness (NR), then it was assumed that they would still all be deployed, but, due to the lack of readiness, the result is penalised one grade. One of the outputs of FLEETSIM then is the proportion of A, B, ... to F grade responses that occurred for each type of tasking. In this study, we are particularly interested in the occurrences of the five scenarios, but the program provides the grading information for all the taskings.

13. Another output is the average number of days that a given asset is away from its home port or base. These can be compared to current or historic levels as a form of measure of commitment or demand that has been placed on the force structure. For example, a fleet that was too small or unbalanced would likely have higher sea day activity for some classes of assets.

14. In summary, FLEETSIM requires three main types of data inputs: a force structure data set, an activity rate data set, and Task Based Grade Tables. These three data inputs are processed by the scheduling logic of the FLEETSIM model to produce a fleet schedule. Currently, FLEETSIM produces two sets of output data (with further refinement, other outputs could be developed): a distribution of grade results for different taskings, and a measure of the average time spent at sea and away from home port per class. Figure 1 presents a graphical overview of the model with its inputs and outputs.

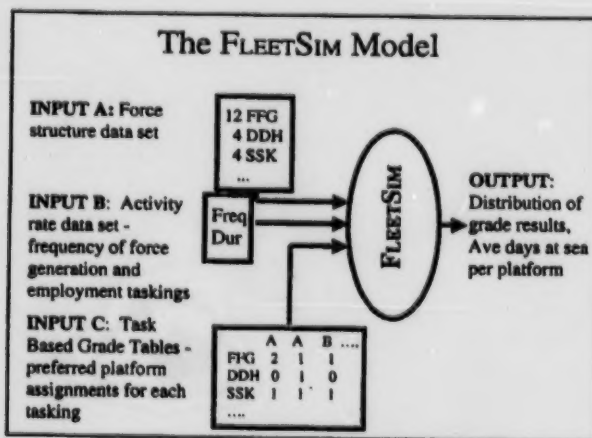


Figure 1: A Graphical Representation of The FLEETSIM Model's Inputs & Outputs

15. By keeping track of a force structure's success in meeting the tasking demands FLEETSIM is able to produce a measure of that force structure's ability to meet Canada's defence needs. Although FLEETSIM results can be viewed in an absolute sense it should be noted that FLEETSIM has not factored in the geo-political and situational aspects of each force employment decision. Thus, the uncertainty of the future world security environment is such that it would not be advisable to use FLEETSIM as a predictive tool. Therefore, FLEETSIM is best employed in generating a *relative* measure of one force structure's success as compared to another. It is this approach that has been adopted by the CMF 2015 FLEETSIM Study.

FLEETSIM LOGIC & INTERNAL RULES

16. It is not difficult to conceptualise the scheduling process. One can imagine a spreadsheet-like plan, whereby the scheduler identifies time slots to schedule the tasks, and then attempts to find appropriate and available assets for the task. The process can be iterative: if the right kind or the right number of assets cannot be found for the tentative period assigned for the task then, either the period must be changed, or the number and type of assets deployed must be changed—to perhaps some less preferred group of assets. There are priorities, policies, and Memoranda of Understanding with other government departments (OGDs) that must be taken into account. These and other constraining factors can make the scheduling process fairly time-consuming.

17. In its internal logic and structure, FLEETSIM attempts to mimic the current scheduling logic. In Annex A, we have provided a summation of our understanding of this scheduling logic as it has been applied in the FLEETSIM model. Our understanding of the scheduling process and procedures was made possible through many consultations with east and west coast scheduling and fleet maintenance staff.

FLEETSIM DATA INPUTS

18. As described above, there are three major data sets that are inputs into the FLEETSIM model. These are:

- a. a force structure data set that details the attributes of the different force structures that are to be evaluated;

- b. an activity rate data set that defines the characteristics of the force generation and force employment activities that need to be scheduled; and,
- c. a Task Based Grade Table data set that defines a graded scale of asset mixes (number and types of assets) that could be assigned to a given tasking.

These data sets can be thought of as the inputs that define the model's resources, demands, and objectives. They allow for a fair amount of flexibility in terms of the parameters and situations that FLEETSIM can be used to study. For example, changing the force structure data set allows one to consider different mixes of maritime assets as well as different overall funding levels. Alternatively, varying the inputs in the activity rate data set allowed the 2015 Study Team to investigate different assumptions on how heavily tasked the maritime forces of the future might be. These three data sets are further described below.

Force Structure Data Set

19. The force structure data set lists the type and number of platforms for each force structure considered. The CMF 2015 Study considered a number of different platforms in a number of different combinations. While a more detailed discussion of each of the platforms and its associated Area warfare³ related capabilities is offered in Reference [9], a brief description of each platform and its associated strengths follow:

- a. CPF: Canadian Patrol Frigate, assumed to be the same ship as in today's fleet with equipment upgrades which maintain its Area level capabilities, as an ASW and AAW surveillance platform, an ASuW responsive platform, and a C4I surveillance platform. It is capable of supporting one maritime helicopter;
- b. CADRE: Command/Control and Air Defence Replacement, a replacement ship to the current fleet of 4 IROQUOIS class destroyers, which retains this class's Area level capabilities as an AAW surveillance and responsive platform, and a C4I surveillance and responsive platform. It is capable of supporting two maritime helicopters;
- c. AOR: Auxiliary Oiler Replenishment, the current fleet of support and replenishment ships with modest self defence capability. Apart from the ability to

³ The CMF 2015 Study applied the naval doctrinal concepts of Area Control and interpreted this as the capability to conduct surveillance and to respond to events extending out to 60-100 nautical miles from the centre of the force (Reference [9])

embark 3 maritime helicopters, it is assumed not to have any Area level warfare capabilities;

- d. MRSV(Basic): Multi-Role Support Vessel – (Basic), assumed to be a replacement AOR with the additional capability to provide more logistical sea-lift capability than the current AOR does. This platform can support three maritime helicopters;
- e. MRSV(Loaded): Multi-Role Support Vessel-(Loaded), assumed to be a replacement AOR with enhanced logistical sea-lift capability and additional Area level capabilities in the areas of AAW and C4I surveillance and responsiveness. This platform can support three maritime helicopters;
- f. SSK: conventionally powered submarine with an ASW capability, assumed to be the Upholder class of submarine with Area level capabilities as an ASW and ASuW surveillance and responsive platform;
- g. MCDV: Maritime Coastal Defence Vessel, assumed to be similar to the current fleet of MCDVs with an Area level capability in Mine Warfare surveillance and responsiveness;
- h. MPA: Maritime Patrol Aircraft, assumed to be similar to the current fleet of Aurora aircraft with an Area level capability in ASW surveillance and responsiveness and in ASuW surveillance;
- i. MH: Maritime Helicopter, assumed to be similar to the current fleet of Sea King maritime helicopters with an area level capability in ASW surveillance and responsiveness and ASuW surveillance; and,
- j. CF 18: Canadian Forces Hornet fighter aircraft, assumed to be similar to the current fighter aircraft with an area level capability in ASuW and AAW responsiveness.

20. FLEETSIM has been used with a variety of different force structures, some of which are variations on a force structure which closely mirrors the CF reality of 1997 and hence forth in this paper is known as the baseline force structure. The baseline force structure consists of the various platforms listed in Table 1. The numbers of seagoing platforms represent the total number of those units. However, the numbers of aircraft represent estimates of the number of aircraft that, on average on any given day, are on the flight line, or in other words the number of aircraft that are not in maintenance or dedicated training and, therefore, are available for employment. Aircraft were modelled in this fashion because they were not the focus of this study, there generally are more of them, and they have different scheduling demands and characteristics in comparison with the ship assets.

TABLE 1
TABLE OF THE COMPONENTS OF THE BASELINE FORCE STRUCTURE

PLATFORM	NUMBER	PLATFORM	NUMBER
CPF	12	MCDV	12
CADRE	4	SSK	4
AOR	3	MH	20
MRSV(basic)	0	MPA	16
MRSV(loaded)	0	CF-18	30

One further observation on the values for the number of aircraft contained in Table 1. Compared to current levels, 20 MH and 16 MPA on the flight line on a day to day basis will seem high. The study team applied the axiom that if pushed the CF would commit totally to an effort. Thus, these seemingly high numbers of available aircraft represent the study teams interpretation of the maximum surge capability of these fleets of aircraft.

21. Since this study was primarily a future force structure study, there are any number of possible force structure alternatives which could be considered and compared with each other. In the early stages of the development of FLEETSIM the study team was working with upwards of 35 different force structures. However, for purposes of clarity and focus, this number was culled to the 17 different force structures which are the subject of this report. A complete description of each of these force structures is included in Annex C.

Activity Rate Data Set

22. The activity rate data set is used to define the periodicity and frequency of occurrence of a given activity or tasking. Drawing from a variety of sources, this study has attempted to duplicate the tasking of these various maritime units on a day by day basis for the full range of force generation and force employment activities short of full scale mobilization. The three primary sources for determining the parameters of a given tasking's periodicity and frequency of occurrence are: policy guidelines such as MARCOM's policy on Readiness and Sustainment of its ships (Reference [10]), expert interpretation of fleet activities, and the results of an empirical study of the past fleet activity levels for the period

of 1985-95 (Reference [7]). There is no guarantee that the future types and frequency of tasks will mirror the past; nonetheless, this was considered a good place to begin analysis.

23. The activity rate data set for a given tasking contains six separate components:
- a. the number of days spent doing the activity;
 - b. the number of days spent in a foreign port;
 - c. the distance in sea days from home port;
 - d. the cycle – the length in years of the period in which the activity occurs;
 - e. the frequency of occurrence of the activity within the limits of the cycle; and,
 - f. the probable Julian start date with a range of days before and after the start date which allow for reasonable scheduling flexibility on a year to year basis.

The items a, b, c, e, and f are expected to vary from year to year and this variability has been incorporated into the model through the use of either a triangular distribution or of a range of discrete probability values⁴. An example of these inputs for a biennial multinational naval exercise known as RIMPAC is shown in Figure 2. A complete set of the input values for all the FLEETSIM taskings along with a more detailed explanation of how each of the values was determined can be found in Reference [11].

24. For the majority of the routine peace time force generation and force employment activities, these data sets have been established with reasonable confidence based upon past patterns and policy. The same can not be said for the activity rate data sets of four of the five CMF 2015 Scenarios. Whereas Scenario 1 (Smuggler Interdiction) has had a more consistent rate, Scenarios 2-5 each have had a very low and thus uncertain rate of occurrence over the past twenty years. Although the activities described by these four CMF 2015 Scenarios represent meaningful force employment of CF assets in support of national policy (Reference [8 & 12]), they occur with notable infrequency and are responsive in nature. This makes them difficult to predict using the statistical tools that were employed

⁴ Probability distributions are used in the model to quantify the uncertainty that resides in many of the inputs. For example, it is unlikely that year after year, the same level of resources would be expended on maritime exercises. If the range of likely values is known, or can be estimated then probability distributions like the discrete or triangular can be fitted to the data and used in the model.

for the routine taskings. Instead, the frequency of occurrence of these four scenarios was randomised by the application of a Poisson distribution; a more complete explanation of which can be found in Reference [13].

FILENAME: RIMPAC			
Activity Type:	Formation Level Exercise		Coast: East
Template:	Px-FPort-Task-Fport-Px		
Days Spent Doing Activity (Tri L-M-H):	10.0	17.0	25.0
Days In Foreign Port (Tri L-M-H):	6.6	10.8	22.4
Distance fm Home Port in Sea Days (Tri L-M-H):	5.9	6.0	6.1
Cycle:	2 Year(s)		
Frequency of Occurrence Distribution:			
Tri L-M-H:	0.9	1.0	1.1
Julian Start Date:	140	days before: 28	days after: 42

Figure 2: Example Activity Rate Data Set for a RIMPAC Exercise

25. It is important to appreciate that the frequency of occurrence of the five CMF 2015 Scenarios over a five year period is relatively low. The probabilities of occurrence for Scenarios 1-5, which were applied in this study, are shown in Table 2. There are two different probability mechanisms at work here. For Scenario 1, we used a triangular distribution with the parameters as shown in Table 2. For example, the parameters for Scenario 1 - East are interpreted as follows: there is no chance that there will be fewer than 0 or more than 5.3 Scenario 1's generated in one year; the most likely number of Scenario 1's is 0.80 (or about one per year); and with these three parameters the average number of occurrences of a Scenario 1 is about two per year. The frequency distribution for the other four scenarios is discrete. In this case, using Scenario 2 - East as an example, there is a 1/3 chance that there will be either no, one or two occurrences of this scenario in a five year period. Thus a review of the values presented in Table 2 show that, while the ability to respond to the needs of a CMF 2015 Scenario is a key measure of performance in FLEETSIM, the actual occurrences of each scenario is not considered to be excessive or artificially high. Efforts to explore the sensitivity of this parameter in relation to the overall performance of FLEETSIM are discussed at greater length later on in this report.

TABLE 2
ASSESSED PROBABILITY OF OCCURRENCE FOR SCENARIOS 1-5

	PARAMETERS FOR THE TRIANGULAR DISTRIBUTION OF THE NUMBER OF OCCURRENCES OF SCENARIO 1 IN ONE YEAR			
	Low	Med	High	Ave
Scenario 1 – east	.00	.80	5.30	2.03
Scenario 1 – west	.00	.80	3.50	1.43
	PROBABILITY OF OCCURRENCE OF A SCENARIO IN A FIVE YEAR PERIOD			
# of Occurrences	0	1	2	>2
Scenario 2 – east	.33	.33	.34	.00
Scenario 2 – west	.70	.30	.00	.00
Scenario 3	.25	.35	.25	.16
Scenario 4	.40	.37	.17	.06
Scenario 5	.40	.37	.17	.06

Task Based Grade Tables

26. The Task Based Grade Tables, hereafter referred to as “grade tables”, determine the type and quantity of assets that are to be deployed in response to a given tasking. In these tables, various combinations of fleet assets are grouped on a sliding, eight point scale and each point on the scale has been assigned a grade ranging from ‘Ideal’ to ‘Failure’ or A to F. Grade tables have been developed for all the activities that are scheduled by FLEETSIM. A more complete description of the development of these tables is contained in References [9] and [11].

27. Most of these activities are routine and not very demanding in terms of fleet resources; consequently, their respective grade tables are relatively simple. As an example, Figure 3 shows the inputs for a RIMPAC tasking. Each vertical column of numbers represents a suitable combination of assets that meet the criteria for the assigned grade. Except for the grade tables for the five CMF 2015 Scenarios, which are found in Reference

[9], the complete set of grade tables used in the FLEETSIM model are contained in Reference [11].

RIMPAC	MANY ASSETS						FEW ASSETS	
	←						→	
RESULTS	IDEAL	VERY GOOD	ADEQUATE	MARGINAL	MEDIOCRE	POOR	VERY POOR (TOKEN)	
CADREs	1 1 1	1 1 1	1 1 1	1 1 1	1 1	1	1	
CPEs	2 2 1 2	2 2 1 2	2 2 1 2	2 2 1 2	2 3 1 2	1 2	1	
AORs	1	1	1	1				
MRSV-b	1	1	1	1				
MRSV-J	1 1 1	1 1 1	1 1 1	1 1				
SSKs	1 1 1 1	1 1 1 1	1 1 1 1	1 1	1 1		1	
MCDVs								
HS	7 7 6 5	7 7 6 5	7 7 6 5	7 7 6 5	4 3	3 2	2 1	
MPA	2 2 2 2	2 2 2 2	1 1 1 1				2	
CE-18	6 6 6 6	3 3 3 3						

Figure 3: Sample Task Based Grade Table for a RIMPAC Exercise

A careful read of this sample table may leave the reader with the impression that the seaborne assets do not start to change until below the 'Adequate' grade. While this is the case in this table, each tasking has different rubrics and this observation is by no means a steadfast rule. Each table was built to reflect the sliding scale nature of a grade table and to situate the 'Adequate' grade, as best as possible, at a desirable and acceptable but not inflated level of resource demand. A greater discussion of how these tables were developed can be found in References [9] and [11].

28. The possible combinations of assets which could be used to respond to one of the five CMF 2015 Scenarios are built upon the Canadian Task Group concept as it is broadly articulated in the 1994 Defence White Paper and the Defence Planning Guide 1998 (References [8 & 12]). Because the majority of these scenarios call for the deployment of a task group level response they are necessarily complex and very resource intensive – doubly so, as the tables must be made flexible enough to account for the permutations that are introduced when many different force structures are under consideration. For example, in the grade tables for Scenario 2 that were used in this study, there are six different asset mixes that were defined as 'Adequate' and a total of twenty eight different asset mixes that were defined as 'Very Good'. An example of the 'Very Good' portion of the Scenario 2 Task Based Grade Table is shown in Figure 4. A complete explanation and description of

the Task Based Grade Tables for the five CMF 2015 scenarios that were used in FLEETSIM is contained in Reference [9].

SCENARIO 2	
VERY GOOD	
-basic White paper/DPG TG	
RESULTS	COMBINED
CADREs	2 1 2 1 1 2 1 2 1 2 1 2 2 1 2 1 2 2 1 3 1 1 2
CPFs	2 3 2 3 2 3 1 2 1 2 1 1 2 2 3 2 3 2 3 1 3 4 3 4 3 4 2
AOPs	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
MRSV basic	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
MRSV loaded	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
SSGs	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
MCDVs	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
HS	8 8 8 8 7 8 8 7 8 7 8 8 8 7 8 8 8 8 8 8 8 8 8 8 8
MPA	4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
CF-18	8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8

Figure 4: Sample Task Based Grade Table for the Scenario 2 'Very Good' Grade

29. With a more complete understanding of the inputs and logic of FLEETSIM we can now begin to look at some of the results that FLEETSIM produces and the analysis that flows from these results.

III. RESULTS

30. FLEETSIM provides a wide range of different data streams that can be used to track and measure the success of the scheduling efforts for a given force structure. Before presenting the results three key measures of effectiveness (MOEs) will be introduced and explained. These three MOEs are: a Measure of Task Availability, an Aggregate Measure of Scenario Scheduling Success, and Average Sea Days. We will then present the results of the FLEETSIM exploration of different force structures as well as a number of excursions that illustrate the impact of increasing or decreasing the tempo of scenario based operations and of accepting or rejecting normal readiness units.

THE THREE KEY MEASURES

The Measure of Task Availability

31. The Measure of Task Availability (MTA) for a given force structure and task is a measure of the model's ability to successfully schedule the assets required for a given task. FLEETSIM groups the various tasks into fourteen broad groupings. Nine of these groupings cover the routinely scheduled force generation and force employment tasks that Canada's Maritime Forces conduct on a yearly basis. The remaining five groupings represent the five CMF 2015 Scenarios which are force employment tasks that FLEETSIM randomly generates.

32. In the course of a simulation, FLEETSIM records the number of occasions in which a task in each grouping is scheduled and the level of success which was achieved (the grade result) of each attempt. As previously described, there are eight different grades ranging from 'Ideal' to 'Failure'. In the case of the five CMF Scenarios, the 'Adequate' grade has been anchored to the level which best equates to a 1994 White Paper or DPG 97 based task group (see Reference [12] for a more detailed explanation of this assumption). In early excursions with FLEETSIM, the model was programmed to select the best response available to answer the requirements of the task, i.e. it always attempted to find an 'Ideal' grade first and then work down the grade table. The CMF 2015 study team later decided that this assumption led to some overly ambitious early assignments during a simulation, especially, in the five CMF 2015 Scenarios, causing problems downstream in satisfying subsequent tasks. Thus, it was decided that, in the case of the five CMF 2015 Scenarios, FLEETSIM

would ignore the 'Ideal' and 'Very Good' grades and start by trying to provide an 'Adequate' grade response. At the end of the simulation run, FLEETSIM calculates the percentage of occurrences of each task in each grouping that were satisfied with a given grade of assets. This constitutes the MTA for a given grouping of tasks.

33. This is better illustrated with an example (for ease of explanation, the numbers used here are approximations of those actually used in the model.) In the case of Scenario 1 (Smuggling Interdiction), Canada's Maritime Forces are expected to respond to an occurrence of Scenario 1 on average twice a year. Thus for a five year period, Scenario 1 may occur ten times. Each time a Scenario 1 occurs, FLEETSIM tries to find, at best, an 'Adequate' grade set of assets. If it cannot find assets to fill the 'Adequate' grade then it works its way down the scale until it finds a suitable and available asset mix and records the corresponding grade. Thus, in this simplified example, over the five year period, six occurrences might have been 'Adequate', three might have achieved a 'Marginal' grade and the last one might have only scored a 'Poor' grade. These results can be used to estimate the probability of obtaining a given grade. Table 3 displays a summary of this example.

TABLE 3
TABLE OF EXAMPLE MTA RESULTS

GRADE	# OF OCCURRENCES	PROBABILITY OF OBTAINING A GIVEN GRADE
'Adequate' or C	6	.6
'Marginal' or D	3	.3
'Mediocre' or E+		.0
'Poor' or E	1	.1
'Token' or E-		.0
'Failed' or F		.0
TOTAL	10	

From this table, the probability of obtaining an 'Adequate' or C grade (denoted as $P(C)$) is a partial expression of Scenario 1's MTA. In this example, given all the factors and variables that are at play in FLEETSIM, one five year period is insufficient time to generate statistically sound results. However, when FLEETSIM is run many times, the resulting MTAs become

accurate measures of a force structure's success at meeting the tasking demands that have been placed upon it. Table 4 is an example of the FLEETSIM results for a Scenario 1 tasking run 1,000 times with the baseline force structure. Our notation for the probability of obtaining a particular grade x for Scenario 1 is: $S_1P(x)$.

TABLE 4

TABLE OF SCENARIO 1 MTA RESULTS - BASELINE FORCE STRUCTURE

GRADE (X)	# OF OCCURRENCES	PROBABILITY OF OCCURRENCE - $S_1P(x)$
'Adequate' or C	12319	0.712
'Marginal' or D	3666	0.212
'Mediocre' or E+	995	0.057
'Poor' or E	134	0.008
'Token' or E-	0	0.000
'Failed' or F	193	0.011
TOTAL	17307	1.000

A graph of these results, Figure 5, provides an alternative representation of this data.

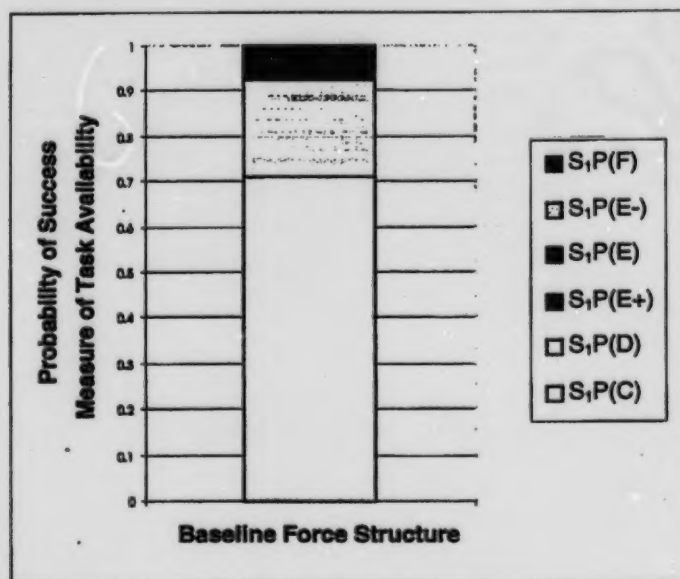


Figure 5: Graph of the MTA for Scenario 1 with the Baseline Force Structure

34. FLEETSIM records the results of the scheduling efforts for all fourteen of the task groupings. A graph of the MTA's for all the task groupings is called an MTA Performance Graph. An MTA Performance Graph displays the success that FLEETSIM had in meeting all the scheduling requirements. In this bar chart, the coloured bars are used to represent the probability that the force structure could provide the assets needed for a given task at a given grade level (recall that for the five scenarios the top two grades were not used.) Task groupings are listed horizontally and, reading from left to right, show the five scenarios followed by nine groupings of routinely scheduled force employment and force generation tasks. Figure 6 is an example MTA Performance Graph for the baseline force structure.

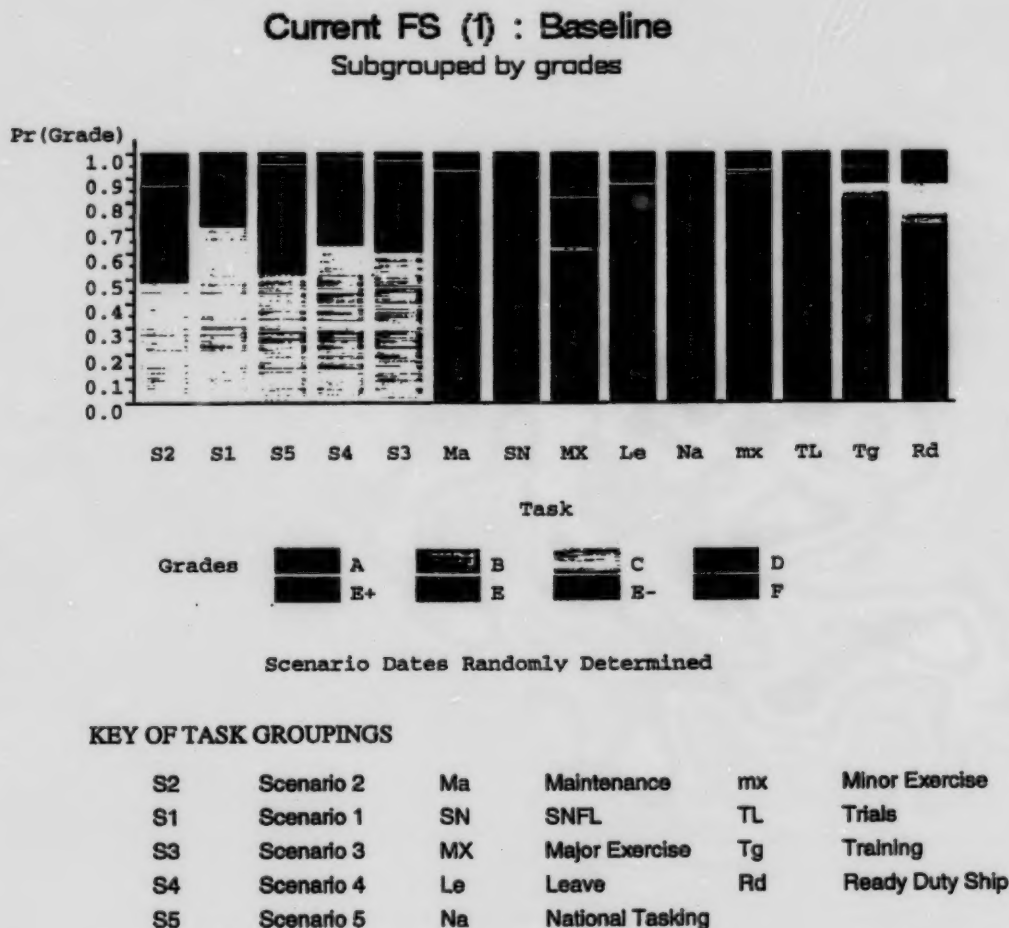


Figure 6: MTA Performance Graph for the Baseline Force Structure

35. While the FLEETSIM model is capable of producing MTA Performance Graphs each time the model is run with a different set of inputs, due to sheer quantity, presenting them all would add confusion and little value to this report. Nonetheless, it is helpful to understand how the MTA is calculated since it is used in the determination of the Aggregate Measure of Scenario Scheduling Success, which is discussed in the next section.

Aggregate Measure of Scenario Scheduling Success

36. The Aggregate Measure of Scenario Scheduling Success is a measure which offers a more concise representation of a given force structure's performance. Since the overall objective of Canada's Maritime Forces is to be able to respond to national or international events, the CMF 2015 Study Team decided to average the MTAs for the five CMF 2015 Scenarios and to call this measure the Aggregate Measure of Scenario Scheduling Success or the AS(x) score where x represents a grade level. Thus:

$$AS(x) = \frac{S_1P(x) + S_2P(x) + S_3P(x) + S_4P(x) + S_5P(x)}{5} \quad (1)$$

where

$S_yP(x)$ = Scenario y's probability of obtaining grade x

37. The AS(x) score is then used as the measure with which to compare the performance of one force structure with another. Thus, the AS(C) score for the baseline force structure is calculated by averaging the $S_yP(C)$ MTA results for each of the five scenarios. An example using the results from the baseline force structure is shown in Table 5.

TABLE 5
CALCULATION OF THE AS(C) SCORE FOR THE BASELINE FORCE STRUCTURE

	$S_1P(C)$	$S_2P(C)$	$S_3P(C)$	$S_4P(C)$	$S_5P(C)$	AS(C)
P(C) MTA	0.71	0.49	0.61	0.64	0.53	0.59

This result can be represented graphically as is shown in the example in Figure 7.

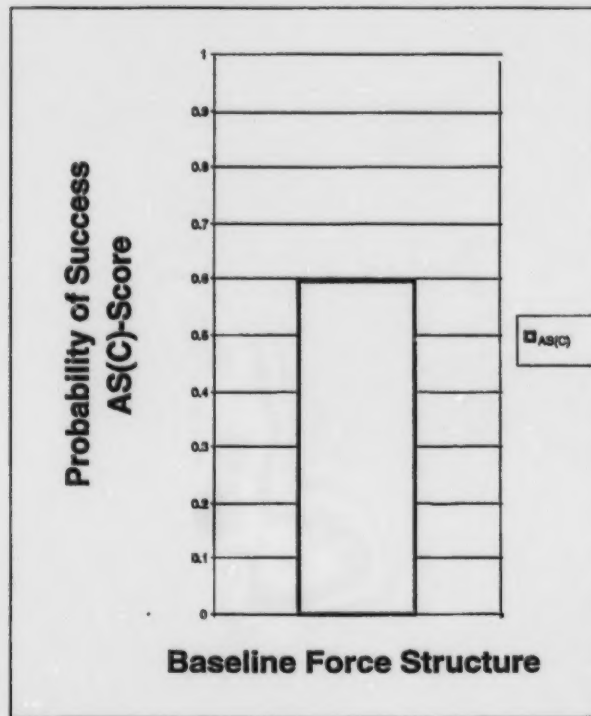


Figure 7: Graph of AS(C) Score for the Baseline Force Structure

38. Graphs such as Figure 7 form the basis of the FLEETSIM results. Figure 7 only displays the AS(C) score, the probability of obtaining an 'Adequate' grade for all five scenarios. While FLEETSIM does generate the data that would allow for the calculation of the AS(x) for other grade results, this data is not presented in this report because this study deliberately anchored the 'Adequate' grade on the study team's best interpretation of 'a Canadian Task Group' as called for by the 1994 Defence White Paper, Reference [12]. For this reason all subsequent graphs presented in this report will show a given force structure's AS(C) score.

Average Sea Days

39. The Average Sea Days (AveSD) is based on the number of days that FLEETSIM scheduled the fleet to be at sea doing any of a number of different tasks. Simply put, it is the annual average days spent at sea per ship per class. At a very macro level, it is an attempt to quantify the demand placed on a given force structure by the navy's predicted and unforeseen force generation and force employment requirements. This measure shows some of the differences between two different force structures which may have relatively similar AS(C) scores but notably different levels of work in terms of days spent at sea. To illustrate, the AveSD for the five classes of ships that comprise the baseline force are presented in the following table, Table 6:

TABLE 6
EXAMPLE TABLE OF AVESD RESULTS FOR THE BASELINE FORCE STRUCTURE

	CPF	CADRE	AOR	MCDV	SSK
# of Hulls	12	4	3	12	4
AveSD	88.5	101	69.3	54.8	74.2

40. With an understanding of the three different measures which can be used to present the results of a FLEETSIM run, we can move on and review some of the results of comparisons of different force structures using FLEETSIM.

FLEETSIM RESULTS

41. FLEETSIM can be used to compare any number of different force structures to each other on a relative basis. As the CMF 2015 study progressed, the number of force structure alternatives that were considered was trimmed to the seventeen that are described in Annex C. Different excursions under different assumptions based on these seventeen force structures permitted the CMF 2015 Study team to explore the impact of varying the number of AOR, CADRE, and CPF. As well, a comparison of all seventeen force structures, grouped by estimates of the impact on the capital budget over twenty years, allows for a

comparison which incorporates macro costing considerations. The results of each of these FLEETSIM explorations are discussed in detail in the following sections.

Excursions With Different Numbers of AORs

42. With the recent decision to purchase the four Upholder class SSKs and the follow on decision to pay off HMCS PROVIDER, the first excursion which is of immediate interest is the impact of changing the number of AORs. We took the baseline force structure and compared it with two other force structures, one with two AORs and one with four AORs. These three force structures were run with the FLEETSIM simulation 1,000 times each. The AS(C) score based results are shown in Figure 8:

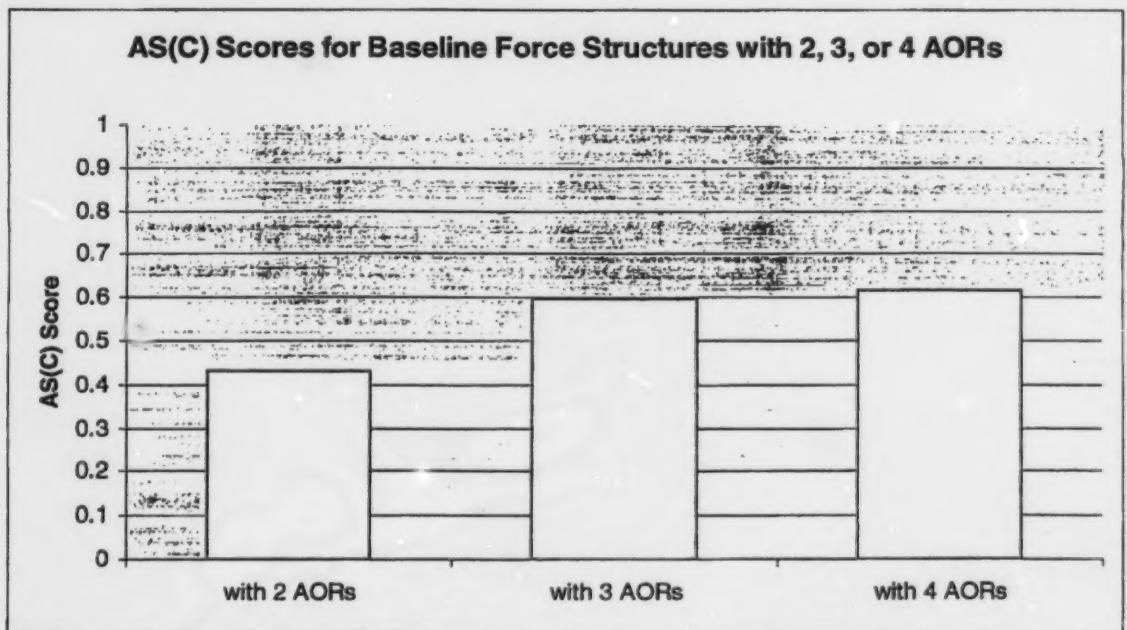


Figure 8: Graph of AS(C) Score for Baseline Force Structures with 2, 3, or 4 AORs

43. The first thing to point out in this graph and all subsequent AS(C) score graphs is that there is always one column which shows the results of the baseline force structure and, as a means of highlighting it, this column is always coloured deep yellow. This graph demonstrates that reducing the fleet from three to two AORs has a significant impact on the

ability of Canada's Maritime Forces to respond to the CMF 2015 Scenarios under the assumptions of the study. It also shows that increasing the fleet from three to four AORs induces only marginal improvement in the ability of Canada's Maritime Forces to respond to the CMF 2015 Scenarios. The AveSD results for these three force structures are presented in Table 7. They show that decreasing the number of AORs increases the days at sea per AOR, but conversely lowers the overall operational tempo of the fleet as a whole. We reason that, in this case, fewer AORs limits the number of possible Task Group deployments thus reducing the overall fleet employment levels. As well, increasing the number of AORs to four lowers the days at sea per AOR, but has little impact on the remainder of the fleet. In this case, an additional AOR may be of little consequence because the overall force structure is limited by the availability of other platforms.

TABLE 7
AVESD RESULTS FOR THE BASELINE FORCE STRUCTURES WITH 2, 3 OR 4 AORS

		CPF	CADRE	AOR	MCDV	SSK
2 AORs	# of Hulls	12	4	2	12	4
	AveSD	84.9	98.9	73	51.5	67.5
3 AORs	# of Hulls	12	4	3	12	4
	AveSD	88.5	101	69.3	54.8	74.2
4 AORs	# of Hulls	12	4	4	12	4
	AveSD	88.8	101.1	55.9	55.6	75.6

44. One question that arises from the results shown in Figure 8 is the question of what limits FLEETSIM from producing results that are better than the AS(C) score of approximately 0.6? Overall performance may be limited by the availability of the resources and/or it may be limited by the intensity of the demand. The authors ran a number of excursions to explore both of these possibilities.

45. In answer to the possibility that the results are limited by resource availability, the authors reviewed the issues of response time and readiness levels. By response time we mean the number of days between the 'decision' to respond to a scenario is made and the time the responding units would depart, begin the transit to the mission, or in some cases start the mission. Since Scenario 1 (Smuggler Interdiction) is a 'very short notice' scenario,

it was given a response time of one day. Based on the current policy of maintaining a task group at high readiness and on ten days notice to deploy (Reference [14]), the remaining scenarios used a response time of ten days. By readiness levels we mean the level of material, personnel, training and equipment readiness at which each unit is maintained at throughout that unit's long term maintenance cycle. Ships normally are either at high readiness (HR), nominally at a 90% of overall readiness; normal readiness (NR), or at 75% of overall readiness; or extended readiness (ER), either in a major maintenance cycle or otherwise not able to respond to a major tasking without significant time or effort. As well, these levels of readiness may be further amplified with a number value which attempts to quantify the time, in numbers of days, that it would take to make the unit fully operationally ready. For example, HR10 would refer to a unit, which is maintaining a high readiness level and could be made ready for an operational deployment in ten days. A unit at NR90 is being maintained at a normal readiness level and could be made ready for an operational deployment in 90 days. Furthermore, according to current policy, (Reference [10]), ships cycle through different levels of readiness in the course of operational cycles. Briefly, frigates and destroyers cycle out of a major refit/maintenance period and up to HR, maintain HR for two years, cycle down to and maintain normal readiness (NR) for two years before re-entering another major refit/maintenance period. Because of their fewer numbers, AORs and the three Oberon class submarines are maintained at HR10 when not in a major refit.

46. The question that the authors wrestled with was how rigid is this relationship between response time and readiness. FLEETSIM has been programmed to schedule ships according to the above mentioned readiness and sustainment policy. As well, it was reasoned that one would not want to deploy unprepared ships into a conflict or potential conflict situation. Accordingly, FLEETSIM was initially programmed with logic that selected only high readiness units for Scenarios 2-5 (although a unit at NR was considered to be an 'Adequate' response to the less demanding needs of Scenario 1.) Thus, the results shown previously in Figure 8 record only the selection of high readiness units to participate in the Scenarios 2-5. On the other hand, if both high or normal readiness ships were deployable, then one would expect to see higher levels of success in a given force structure's ability to achieve a favourable AS(x). Accordingly, we altered the FLEETSIM scoring logic to accept either HR or NR units for Scenarios 2-5 taskings and, not surprisingly, obtained notable improvements in the AS(C) score. Figure 9 shows both the level achieved with only HR units in yellow (a repeat of the results from Figure 8) and the additional component, in blue, which is achieved by allowing the selection of NR units.

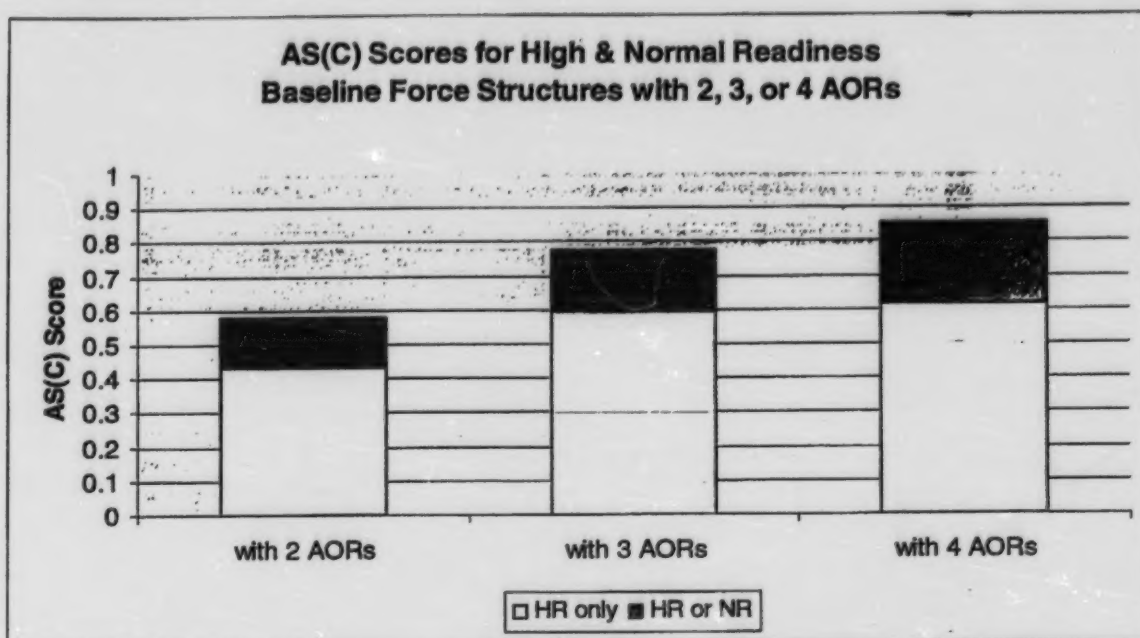


Figure 9: Graph of AS(C) Score for HR and NR Force Structures with 2, 3, or 4 AORs

47. Figure 9 shows graphically that allowing the inclusion of normal readiness units in the task group permits a much higher level of success in deploying an 'Adequate' grade response to Scenarios 2-5. One also sees the start of some separation in the overall performance between a baseline force structure with three AORs and one with four AORs. What has not been captured in this study is the attendant increased risk associated with deploying a normal readiness unit to a potentially hostile operation.

48. These two excursions, with different levels of readiness, help to demonstrate why FLEETSIM is not able to find 'Adequate' grade responses all the time. However, there still remains a notable difference between the demand and response, which leads us to consider the role that the level of demand has on the FLEETSIM results.

49. As has been previously discussed, FLEETSIM uses activity rates for the five scenarios, which are considered to be low, and are, as well as can be predicted, fitted to the frequencies of occurrence over a recent ten year period. Nonetheless, since each individual scenario's occurrence is initiated randomly there is a chance that two and even three scenarios may occur simultaneously. Clearly, the simultaneous deployment of two or more task groups for extended periods of time is a demanding event especially if all the units

must be at high readiness. Accordingly, the CMF 2015 Study Team decided to explore the impact of changing the level of demand on the FLEETSIM results.

50. This question was approached from two sides: that of minimising the overlap of the scenarios and that of doubling the demand rate. Minimising the overlap of the scenarios entailed modifying the logic of FLEETSIM so that it would try to schedule all the scenarios in such a way as to minimise the overlap of any two scenarios. Minimising the overlap was called Non-Overlapping logic and did not entail changes to the scenario activity rates (otherwise known as the demand rate.) The authors thought that by introducing the Non-overlapping logic that they were exploring the situation where policy dictates might only allow for participation in one Scenario 2-5 like mission at any one time. Doubling the demand rate involved increasing the frequency of occurrence of each of the scenarios by a factor of two. The results of applying Non-Overlapping, Normal and Double demand rates to FLEETSIM are shown in Figure 10 and Tables 8 & 9.

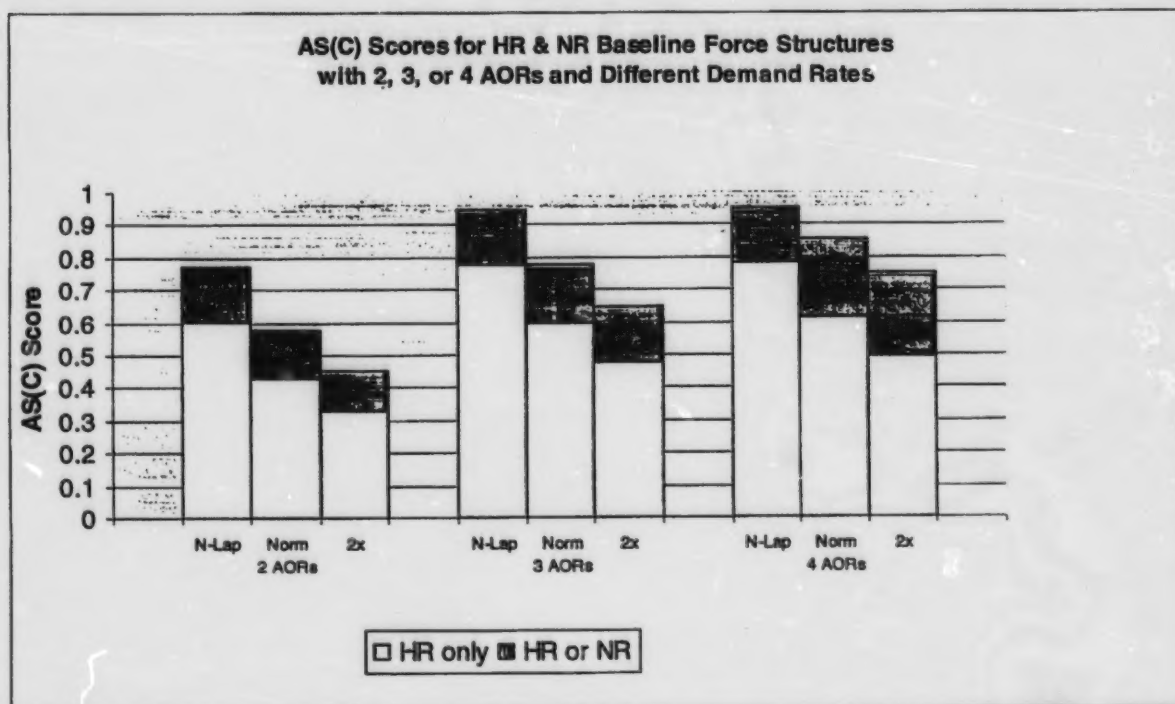


Figure 10: AS(C) Score for Force Structures with 2, 3, or 4 AORs & Different Demand Rates

TABLE 8
**AVESD RESULTS FOR FORCE STRUCTURES WITH 2, 3 OR 4 AORS & NON-
OVERLAPPING LOGIC**

		CPF	CADRE	AOR	MCDV	SSK
2 AORs	# of Hulls	12	4	2	12	4
	AveSD	82.5	96.7	73.7	51.5	68
3 AORs	# of Hulls	12	4	3	12	4
	AveSD	86.5	98.8	68.5	54.4	73.9
4 AORs	# of Hulls	12	4	4	12	4
	AveSD	87.1	99	53.6	54.1	73.9

TABLE 9
**AVESD RESULTS FOR FORCE STRUCTURES
WITH 2, 3 OR 4 AORS & DOUBLE DEMAND**

		CPF	CADRE	AOR	MCDV	SSK
2 AORs	# of Hulls	12	4	2	12	4
	AveSD	94.5	116.7	93.3	60.7	82.4
3 AORs	# of Hulls	12	4	3	12	4
	AveSD	97.5	118.5	85.7	65.1	90.9
4 AORs	# of Hulls	12	4	4	12	4
	AveSD	97.9	118.6	72.4	67.5	95

51. Figure 10 shows that running FLEETSIM with Non-Overlapping logic has a positive effect on the AS(C) score for each of the three force structures under consideration. If FLEETSIM selects only high readiness units then baseline force structures with three or more AORs are able to provide an 'Adequate' grade response to the Scenario taskings with a probability greater than .76. If it is allowed to select normal readiness ships then the same force structures are able to provide an 'Adequate' grade response with a notably high probability of greater than .94. The conclusion which we draw from this is that baseline force structures with three or four AORs are of sufficient resource depth to meet any one

scenario that may arise but shows signs of being unable to respond reliably when they are asked to provide forces to more than one major scenario at the same time.

52. If we compare the AveSD values for force structures with Normal (Table 7) and Non-Overlapping (Table 8) demand rates, we see very little difference between these two results. Since the actual demand rate of the Normal and Non-Overlapping runs are the same (the only difference is the Non-Overlapping logic attempts to artificially minimise the concurrency the scenarios) one would not expect a noticeable difference in these results. As we shall see later on, other force structures which are more asset rich have less of a problem dealing with additional demands of scenario concurrency.

53. Figure 10 also demonstrates that doubling the demand rate has a negative impact on the AS(C) score for each of the three variations of the baseline force structure. When only HR units were selected for major scenarios even a baseline force structure with four AORs was not able to provide an 'Adequate' grade response with a probability of greater than 0.50. If FLEETSIM is allowed to select normal readiness ships, the probability of providing an 'Adequate' grade response for a baseline force structure with three AORs increases to .64 and for a force structure with four AORs it increases to .74. Again, by inference, this is an indication that doubling the demand rate increases the level of scenario concurrency which has a corresponding detrimental impact on the ability of these three variations of the baseline force structure to provide 'Adequate' grade responses to major scenario taskings.

54. This conclusion is further borne out when the values for the AveSD for Double Demand force structures (Table 9) are compared with the results from Normal Demand force structures (Table 7). In this case we see that doubling the frequency of occurrence of the scenarios drives up the AveSD values by between 15-30% across the different platform classes. This represents a significant increase in resource utilisation.

55. This issue of concurrency is difficult to quantify and is something which this study has attempted to investigate by conducting excursions in either direction along the demand continuum. Overall, a number of explorations involving the same three variations of the baseline force structure has demonstrated that, in general, force structures with less than three AORs are notably less responsive, and that a baseline force structure with four or more AORs is marginally more responsive than the FLEETSIM baseline force structure with three AORs. As well, allowing task groups to deploy with normal readiness ships and

minimising the concurrency of the major scenarios improves force structure performance, while increasing the frequency of occurrence of the scenarios had a notably detrimental affect upon overall force structure performance. These three force structures differed only in the number of AORs that each had. The next section presents the results of excursions with force structures that only differ in the number of CADRE platforms available.

Excursions With Different Numbers of CADRE Platforms

56. Given the age of the current class of Tribal warships and the potential need to replace them in the next twenty years, the next area of interest to the CMF 2015 Study Team was the effect that varying the numbers of CADRE ships would have on responsiveness. We took the baseline force structure and compared it with two other force structures, one with two CADREs and one with no CADREs. These three force structures were run with the FLEETSIM simulation 1,000 times each at the Normal demand rate and allowing for the assignment of HR only, and HR and NR platforms to task groups. The AS(C) score based results for these force structures under these conditions are shown in Figure 11 and the AveSD results are presented in Table 10:

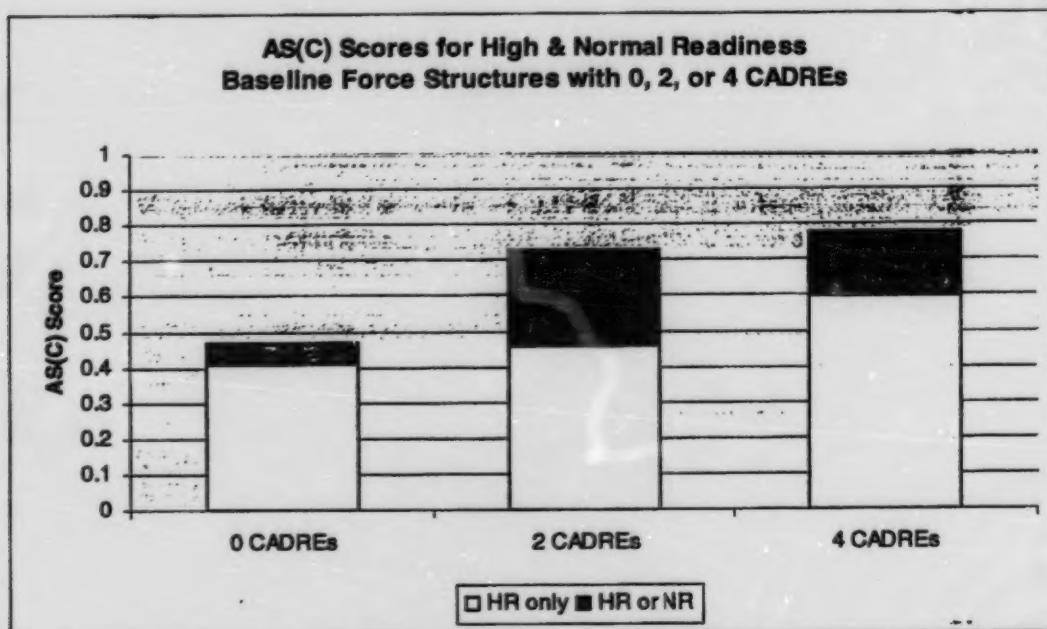


Figure 11: AS(C) Score for Force Structures with 0, 2, or 4 CADREs & Normal Demand

TABLE 10
AVESD RESULTS FOR FORCE STRUCTURES
WITH 0, 2 OR 4 CADRES & NORMAL DEMAND

		CPF	CADRE	AOR	MCDV	SSK
0 CADRES	# of Hulls	12	0	3	12	4
	AveSD	104.2	0	60.9	52.4	61.7
2 CADRES	# of Hulls	12	2	3	12	4
	AveSD	95.1	124.4	67.2	54.8	72
4 CADRES	# of Hulls	12	4	3	12	4
	AveSD	88.5	101	69.3	54.8	74.2

57. The results displayed in Figure 11 show the impact of reducing the number of CADREs in the current force structure. A force structure without the capabilities represented by the CADRE class would have a low probability of successfully providing the level of response that would be expected of it in the context of current national policy. Since two of the scenarios (Scenarios 2 & 5) call for the capabilities resident in the CADRE ship, it is these scenarios which would suffer the most in terms of being unable to provide an 'Adequate' grade response⁵. Also evident is the impact of a decision to accept normal readiness platforms. The impact of losing two CADREs is more severe if only HR ships are selected (.59 to .46), and is less severe if both HR and NR units are selected (.78 to .73).

58. Table 10 also sheds light on the impact that varying the number of CADRE platforms would have on overall fleet performance. These results show us that a force structure with only two CADREs would have higher utilisation rates of the CADREs. As well, as the number of CADREs declines, more of the work that can't be performed by the CADREs is shifted to the frigates increasing the AveSD of the CPFs. Finally, because of the lower level of response that can be offered by force structure with no CADREs, it has lower AveSD values for the remaining force structure components.

⁵ For clarification, because Scenarios 2 & 5 tend towards the high end of the continuum of conflict scale they have the capabilities of the CADRE platform in all the asset mix options at the 'Adequate' grade. Scenario 1 does not call for a task group at the 'Adequate' grade and Scenario 3 & 4 include asset mix options that provide an adequate task group with and without a CADRE-like platform, (Reference [9]).

59. With respect to the results involving NR platforms, one must be careful in interpreting these latest observations. Working with a force structure with two CADREs and allowing normal readiness platforms to respond to scenarios is riskier than with a force structure with four CADREs. The two CADRE force structure would spend more time at sea, may require more maintenance (regardless of the level of utilisation, FLEETSIM applies a fixed set of maintenance requirements for all force structures, which may result in optimistic availability results,) and would need to deploy NR units on operational missions more often. In a simplistic fashion, this can be equated to a rough measure of uncertainty. In other words, the larger the portion of the bar graph which is shaded in blue the greater the level of uncertainty associated with the responsiveness of a force structure. Thus, while force structures with two or four CADREs may have very similar levels of responsiveness if normal readiness units are deployed on operational taskings, the former has a much higher measure of uncertainty as seen by the greater portion of blue in its bar graph.

60. In addition to these excursions, these three force structures were also run in the FLEETSIM simulation 1,000 times each, with Non-Overlapping and Double demand rates. The results for these force structures are shown in Figure 12 and Table 11.

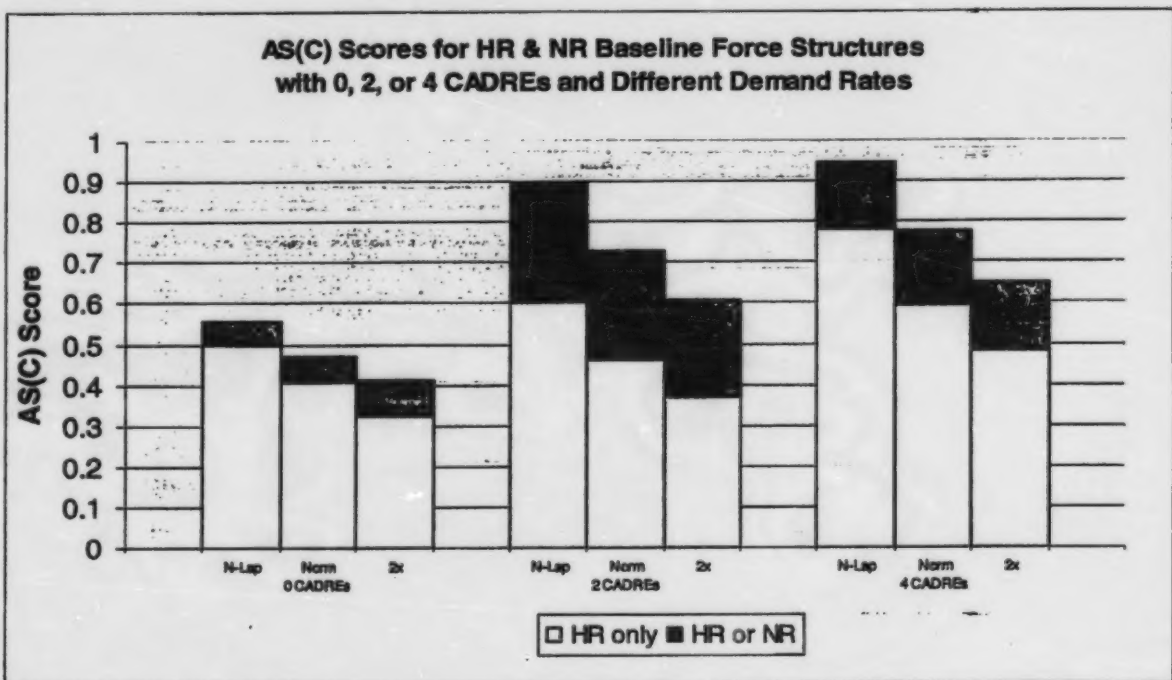


Figure 12: AS(C) Score for Force Structures - 0, 2, or 4 CADREs & Different Demand Rates

TABLE 11
AVESD RESULTS FOR FORCE STRUCTURES
WITH 0-4 CADRES & NON-OVERLAPPING LOGIC

		CPF	CADRE	AOR	MCDV	SSK
0 CADRES	# of Hulls	12	0	3	12	4
	AveSD	101.8	0	61.7	52.5	63.1
2 CADRES	# of Hulls	12	2	3	12	4
	AveSD	92.5	125.8	67.4	54.8	72.5
4 CADRES	# of Hulls	12	4	3	12	4
	AveSD	86.5	98.8	68.5	54.4	73.9

61. Again, in Figure 12 we see the notable and predictable improvement that is obtained when the FLEETSIM model is asked to schedule the scenarios so as to minimise the level of demand by lowering the level of scenario concurrency. The baseline force structure with no CADRES shows improvement, but overall its performance is still low. The baseline force structure with two CADRES improves under these conditions and if normal readiness units are accepted on scenario taskings then it improves noticeably and has an AS(C) score of close to .90. Finally, the baseline force structure with four CADRES does very well under these conditions, obtaining a AS(C) score for high readiness selections of .78 and for high and normal readiness selections of .95. Similarly, we see slight but consistent declines in the AveSD values for the Non-Overlapping logic in comparison with the Normal demand.

62. Overall, explorations with three variations of the baseline force structure have demonstrated that, under the current readiness constraints, force structures with no CADRES and with only two CADRES are notably less responsive than the FLEETSIM baseline force structure with four CADRES. As was demonstrated earlier in the presentation of force structures with different numbers of AORs, minimising the concurrency of the major scenarios improves force structure performance across the board for these three force structures. These three force structures differed only in the number of CADRES that each had. The next section presents the results of excursions with force structures that only differ in the number of CPF type platforms available.

Excursions With Different Numbers of CPF Platforms

63. The current fleet of twelve CPFs was built in the early 1990s and, assuming a thirty year life span, would reasonably be expected to be under consideration for replacement shortly after the year 2015. Therefore, from the perspective of completeness and model sensitivity, it was logical to explore the impact that different numbers of CPFs would have on responsiveness. In these excursions we compared the baseline force structure with three other force structures: one with ten CPFs, one with eight CPFs, and one with six CPFs. These four force structures were run with the FLEETSIM simulation 1,000 times each, at the Normal demand rate and allowing for the assignment of HR only, and HR and NR platforms to task groups. The results for these force structures under these conditions are shown in Figure 13 and in Table 12.

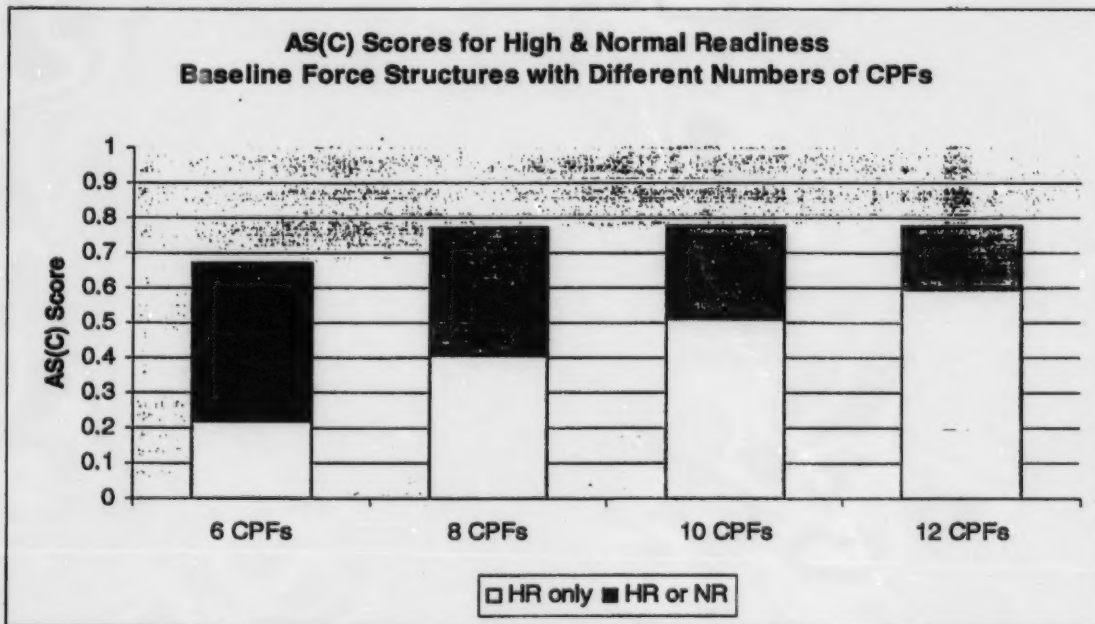


Figure 13: AS(C) score for HR & NR Force Structures & Normal Demand

TABLE 12
AVESD RESULTS FOR FORCE STRUCTURES
WITH 6, 8, 10, OR 12 CPFs & NORMAL DEMAND

		CPF	CADRE	AOR	MCDV	SSK
6 CPFs	# of Hulls	6	4	3	12	4
	AveSD	127.8	99.7	61.1	36.4	67.9
8 CPFs	# of Hulls	8	4	3	12	4
	AveSD	114.3	101.9	66.5	55.5	71.6
10 CPFs	# of Hulls	10	4	3	12	4
	AveSD	98.7	101.1	67.7	55.6	71.8
12 CPFs	# of Hulls	12	4	3	12	4
	AveSD	88.5	101	69.3	54.8	74.2

64. These results show the impact of reducing the number of CPFs on the responsiveness of the current force structure. When Scenarios 2-5 only accept high readiness units then responsiveness declines steadily with declining numbers of CPFs. When units at NR or HR are accepted for scenario taskings, variations of the force structures with 8, 10, or 12 CPFs are more or less equally responsive. Responsiveness only begins to decline after the number of CPFs has been reduced to six. This is an indication that, as long as there are eight or more CPFs in the force structure and readiness is not a factor, then the responsiveness of a force structure is not limited by the availability of CPFs. However, there would be a notable impact in the average number of sea days for the CPFs. Table 12 shows us that as the number of CPFs decline, the AveSD for this class of platform steadily increases.

65. In addition to these excursions, these four force structures were also run in the FLEETSIM simulation 1,000 times each, with Non-Overlapping and double the demand rates. The results for these force structures under these conditions are shown in Figure 14 and Table 13.

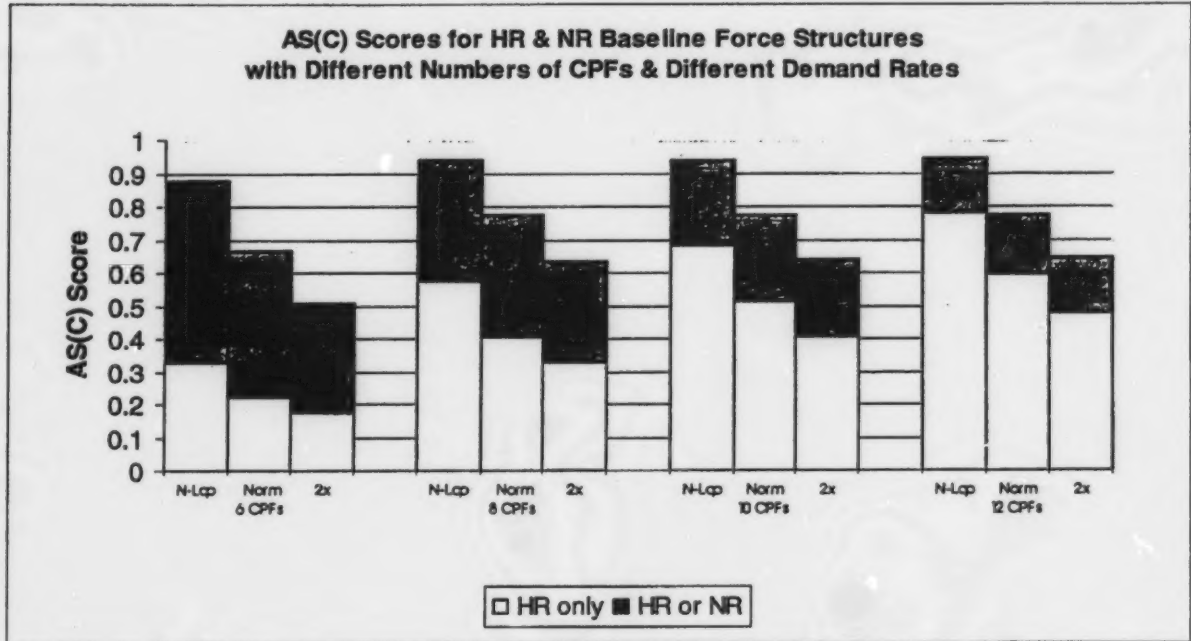


Figure 14: AS(C) score - Force Structures of 6 – 12 CPFs & Different Demand Rates

TABLE 13

AVESD RESULTS - FORCE STRUCTURES 6-12 CPFS & VARYING DEMAND RATES

		CPF	CADRE	AOR	MCDV	SSK
6 CPFs	# of Hulls	6	4	3	12	4
	AveSD – N Lap	125.1	98.1	61.9	36.6	69
	AveSD – 2x	138.8	115.6	79	44.6	85.9
8 CPFs	# of Hulls	8	4	3	12	4
	AveSD – N Lap	111.5	100.2	66	55.4	71.6
	AveSD – 2x	125.2	119	83.5	66.8	89.6
10 CPFs	# of Hulls	10	4	3	12	4
	AveSD – N Lap	96.7	99.6	68.5	55.7	72.8
	AveSD – 2x	109.1	118.3	85	66.2	89.8
12 CPFs	# of Hulls	12	4	3	12	4
	AveSD – N Lap	86.5	98.8	68.5	54.4	73.9
	AveSD – 2x	97.5	118.5	85.7	65.1	90.9

66. As has been shown in earlier excursions, minimising the level of scenario concurrency notably increases the responsiveness of the force structures across the board. As well, when only high readiness units are selected for scenario taskings we see declining responsiveness with declining numbers of CPFs. However, when normal readiness units are accepted we see little difference between and a very high level of responsiveness for the baseline force structures with 8, 10 or 12 CPFs and less but still very good results for the force structure with six CPFs. Again, for force structures with eight or more CPFs, this is indicative of a set of force structures that, in terms of their responsiveness, are not constrained by the number of CPFs. A second observation can be made based upon the trend in AveSD for the CPFs and the other platform classes. With declining numbers of CPFs the results show an increase in AveSD and a corresponding decline in Ave SD values for the other platforms – a decline which begins to accelerate notably when the number of CPFs falls from eight to six. This is an indication of how much more work would be required of each CPF as their total numbers decline. As well, the decline in the AveSD of the other platforms is interpreted as an indication of the force structures' with lower numbers of CPFs increasing inability to support task group level efforts.

Excursions With Different Numbers of SSKs

67. Early in the project the CMF 2015 Study Team created and analysed different force structures which varied in terms of the number of SSKs that each had. However, with the recent decision to purchase four UPHOLDER class submarines from the United Kingdom, these efforts became overtaken by events. The purchase of the UPHOLDER submarine likely means that this platform will remain in service in the CF for upwards of thirty years. This puts this platform's serviceability to well beyond the year 2015 and for this reason analysis of force structures with different numbers of SSK are not presented in this report.

All Seventeen Force Structures Arranged by Estimated Capital Cost and AS(C) score

68. The final set of AS(C) score based results that will be presented in this report is a set that is based on a comparison of seventeen different force structures. These force structures have been grouped by gross estimates of projected, twenty year, capital budget costs (Reference [15]) and sorted within these groups in ascending order of AS(C) score for high

readiness only task groups. The graph of these results is shown on the next page in Figure 15. The accompanying table of AveSD for all 17 force structures is found in Annex D.

69. This final graph presents the results from seventeen force structure excursions of FLEETSIM run 1,000 times each. These seventeen force structures include the eight different force structures that have been presented in the previous sections as well as an additional nine force structures which explored different options. While FLEETSIM could be run with any number of different force structure options, this particular set of seventeen force structures was chosen because it reflected reasonable options that might be considered in the time frame under review (Reference [14]).

70. In general, these results demonstrate that there are a number of reasonably effective force structures that could be used to fulfil our maritime force commitments into the next century. Interestingly, however, one significant observation that follows from a study of these results is that increasing the capital budget does not gain a corresponding increase in overall responsiveness. In other words, the force structures that are grouped in the 'Increase' sub group do not notably perform better than some of the 'Steady Funding' group. In the other direction, when capital budget funding is reduced, the results show an immediate and notable decrease in responsiveness for all the force structures studied.

AS(C) Scores for 17 Different

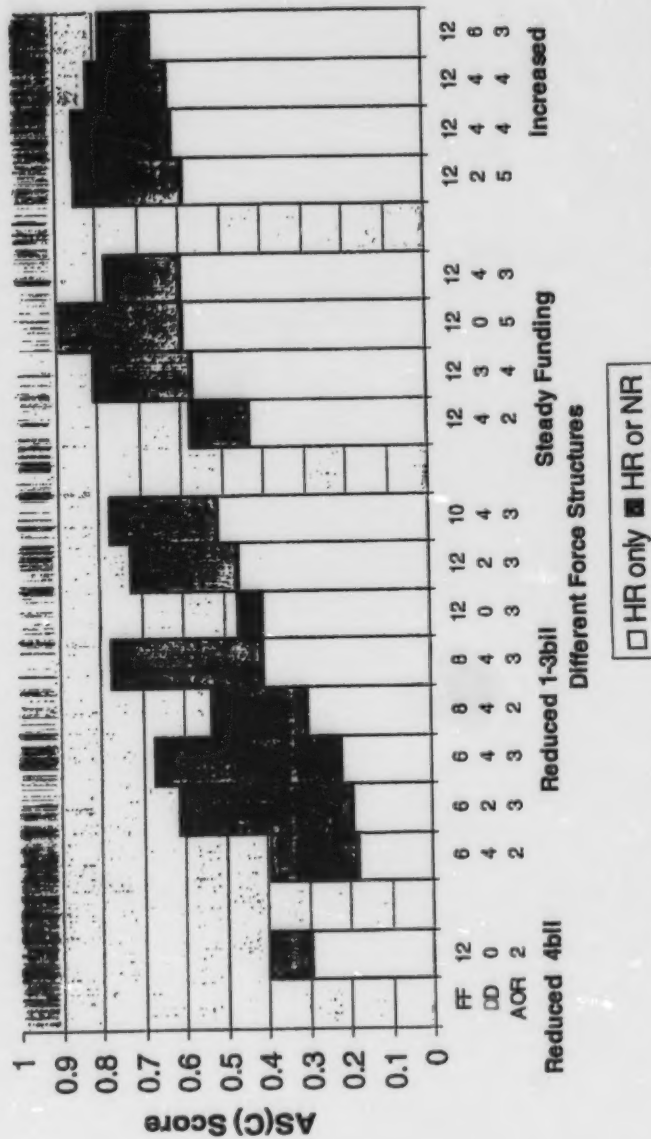


Figure 15: AS(C)-Score for Seventeen Different Force Structures at High and Normal Readiness

IV. DISCUSSION

71. The twofold objective of this report is to describe the FLEETSIM model and to present a summary of the results of the CMF 2015 Study into future forces structure needs based on the use of the FLEETSIM model. In the previous sections, we have described both the model and its inputs as well as the results of a number of explorations using different force structures. In this section, we present a discussion of the model's overall limitations and strengths followed by a discussion of the actual results.

FLEETSIM'S LIMITATIONS

72. There are five aspects of the FLEETSIM model logic and assumptions which warrant discussion before drawing final conclusions on the results produced by FLEETSIM. Each of these aspects is briefly discussed below.

Performance Success or Failure

73. FLEETSIM assumes that the assets which are assigned to an activity will:
- a) actually perform that activity successfully and subsequently be available for further tasking; and,
 - b) not be lost whether due to accident, battle damage, or attrition.

The result is to give an optimistic account of a given force structure's ability to cope with real time actualities such as mission failure or attrition.

Maintenance Considerations

74. One might reason that there is a relationship between the amount of time a platform spends at sea and the amount of maintenance it requires. However, in the absence of evidence to the contrary (Reference [16]), the current study assumed that the maintenance requirements of the platforms did not vary with the platform's age or level of employment. The result again leads to an potentially optimistic account of a given force structure's availability.

Capital Budget Costs and Estimates

75. Since force structure issues are inextricably tied to the department's long term capital budget, this study grouped different force structures based on their projected capital budget costs over a twenty year period. These results are incorporated in the final graph of 17 force structures, Figure 15. A word of caution: these capital budget cost estimates are clearly 'rough order of magnitude' estimations and have not been rigorously worked out. While a more careful estimation of the capital costs of each force structure may provide useful results, given the scale of this study, the authors accepted this level of estimation as sufficient.

Geopolitical and Situational Considerations

76. It is useful to appreciate that the scheduling logic of FLEETSIM does not take into consideration any geopolitical or situational considerations. When a scenario needs to be scheduled, FLEETSIM always attempts to provide the best combination of assets that it can find (in the case of the results presented in this report, this means the best set of 'Adequate' grade assets.) In this respect, FLEETSIM is a robust scheduler. Whereas, in reality there may be scenarios when a commitment of one frigate may, for various geopolitical and situational reasons, be an acceptable national response, in its present form FLEETSIM would have tried very hard to schedule a task group for this mission and would have graded a single frigate response well below an 'Adequate' grade.

77. On one hand this is simply a level of demand question: attempting to factor in these considerations arguably would lower the activity demand levels and this is something that we have already explored by an alternative approach. On another hand, this is a question of policy vice reality. Whereas policy may dictate what we are prepared to commit to, reality may often record the commitment of some but not all of what we are prepared to commit to. Since, the CMF 2015 Phase II Study is a policy-based force structure study, FLEETSIM's logic of scheduling the maximum of what we would be prepared to commit to is consistent with this policy based approach. Secondly, since FLEETSIM's results are being used for a relative comparison, we argue, again, that the decision of whether or not to include geopolitical and situational factors is immaterial to the results since they would be applied equally across the set of force structures under review.

Grade Tables

78. The grade tables are key to determining the performance of a given force structure, but they lack a clear empirical foundation (Reference [9]). However, since they were constructed based on subjective inputs from the CMF 2015 study team and validated through a survey of senior naval and maritime air officers, they represent an ambitious attempt to add further definition to the broad policy directives concerning the composition of a Canadian Task Group. While these grade tables proved to be an important and very useful tool, their validity would be improved by the development of a more objective measure. Regrettably, it was concluded that the effort to measure or quantify these task group capabilities and in turn to aggregate them in some form of over arching task group performance measurement scheme was beyond the scope of this study and was better left to future endeavours.

FLEETSIM'S STRENGTHS

79. While FLEETSIM has its limitations, it also has its strong points, some of which are discussed in the following sections.

More Than Just A Capability Based Study

80. Frequently force structure studies of the past have focussed on one specific asset and have been capability based. The approach adopted in this study was to consider the maritime forces as a whole and to combine platform capability along with actual force generation and force employment issues. Thus, the resulting FLEETSIM model is able to develop a realistic schedule of each force structure's employment level and to measure and compare one force structure's results with another. This allows for a much more comprehensive analysis of any number of different possible force structures, a trait that was often lacking in previous approaches.

Policy Based

81. One of FLEETSIM's strengths is that it creates logical and explicit links between national policy directives and force structure levels. This is achieved through its use of

grade tables which have been built and anchored on the policy requirements of the 1994 Defence White Paper and the department's Defence Planning Guidance 97, and of information on activity rates gleaned from the Fleet Activity Study. These two inputs, the grade tables and the activity rate data set, are derived from a significant amount of explicit and de facto policy based data and information. Thus, FLEETSIM is a tool that helps to make explicit the impact of current national and command level policy on current or future force structure levels. In the difficult process of defining and defending force structure requirements this should prove to be an extremely useful characteristic.

Flexible

82. FLEETSIM is a scheduling model. Given the model's design and the nature of the three main types of input (force structure data sets, activity rate data sets, and grade tables or in other words resources, demand, and objectives), there is a lot of scope to vary any of these inputs, and thus to use this model to explore issues concerning maritime force levels, force employment and force generation. It is the authors' opinion that there is notable potential to employ the FLEETSIM model to explore any number of force generation and/or force employment related questions.

Relative Vs Absolute

83. Another strength of the current FLEETSIM model is that it is an excellent tool for comparing the performance of one force structure with any number of other force structures. Although, as has been pointed out before, it is not necessarily the best tool to study the absolute performance of any one force structure, it is a tool which has the potential to be used for this type of study. That is, with further enhancements to the logic and to the completeness of the data inputs, FLEETSIM could be used to study, in an absolute sense, how one force structure would perform under different levels of demand and funding levels. This is a potential area of further use for the FLEETSIM model.

FLEETSIM FORCE STRUCTURE STUDY RESULTS

84. The results presented in this report centre around an attempt to reply to the question of what type of force structure will best serve Canada's needs in the early years of the coming century. Surely, this is a very difficult question to answer. But having made some reasonable assumptions, this study has made significant advances in linking and translating the often broadly defined national policy objectives into actual numbers of different types of platforms. This in turn is a very useful starting point for probing the issue of Canada's future maritime force structure.

85. In general terms, the results from the different force structures that were run with FLEETSIM and presented in this report show us that:

- a) given the projected level of demand, spending significantly more money from the capital budget does not translate into notably better performance;
- b) spending significantly less money from the capital budget translates into notably poorer performance;
- c) reducing the number of AOR type platforms to two or fewer significantly reduces fleet responsiveness and performance;
- d) reducing the number of CADRE type platforms seriously reduces the CF's responsiveness to the more intensive Scenario's 2 & 5, and also reduces overall fleet flexibility and performance. However, the impact is not as serious as is the case with the AORs;
- e) reducing the number of CPF type platforms has a steady but less rapid impact on fleet performance until the number is reduced to eight or less at which point fleet performance begins to fall off quickly. It is cautioned, however, that the remaining CPF fleet would have a notably higher average sea time and potentially higher maintenance requirements; and,
- f) the overall level of fleet readiness has a significant role to play in the overall fleet performance results, a role which merits further consideration in future studies.

86. Recall that these results and conclusions are very much dependent upon the study's assumptions and inputs. For example, consider the first conclusion above. One might ask, "How can it be that spending more money to obtain more assets does not translate into better performance?" Part of the answer to this question is that obtaining more assets would

likely allow for an adequate response to an increase in taskings, but the forecast level of demand creates a situation where there would be an excess of resources relative to the demand. Another part of the answer to this question may lie in the type of response that is achievable. Recall that these results are based on the AS(C) score or the ability to provide an 'Adequate' response. Although increasing the funding seems to have little impact at this level, it is likely that it has a more pronounced affect on the ability of different force structures to provide 'Very Good' or 'Ideal' level responses. Finally, part of the answer may lie in the type of assets that are added. It is possible that the force structures that were tested in this report did not go far enough in varying the number, and more likely, the type of assets which have the most impact on overall fleet performance. The limited set of 17 force structures is but a subset of all the possibilities. The necessity of limiting the force structure options analysed to a workable number may have introduced certain unintentional and unknown biases and is, perhaps, one area that would merit further investigation.

87. With respect to FLEETSIM's inputs and assumptions, the authors maintain that they are a reasonable reflection of reality. Certainly, any inputs derived from historical sources and current doctrine will have a certain bias towards the current state. Nonetheless, since militaries and their force structures tend to change very slowly (except for times of intense mobilization), it is reasoned that these assumptions and inputs are more likely to hold true than not over the course of a short twenty year timeframe. In terms of the three major inputs, each has its limitations, which we have attempted to identify and address.

88. In the case of the force structure data set, it is only a subset of all the possibilities, it does not support a thorough sensitivity analysis, and it may be subject to certain unintentional and unknown biases. Nonetheless, the results from the studies of those force structures that are presented in this report do shed light on areas of interest concerning the nature and composition of Canada's future maritime forces. At a minimum, it forms an excellent starting point, and should other force structures be of interest, FLEETSIM could be used to study and compare them as well.

89. The major limitation pertaining to the activity rate data inputs is that they may not be an accurate estimate of the level of future force generation and employment tasks. The authors addressed this issue by running excursions that in one case served to reduce the demand and in the other case served to double the demand. The results of these excursions showed us that the model is responsive to variations in the level of demand placed on a

force structure. Furthermore, since this model is being used to compare the relative performance of different force structures, it is argued that it is more important that the demand be applied consistently for the different force structures but less important that the level of demand be accurate.

90. With respect to the grade tables, the authors acknowledge that this is one area which our knowledge and expertise leaves us short of answers. While the approach, which we have adopted, is appealing and has been validated by experts in the maritime environment, as has already been mentioned, it necessarily retains a high component of subjectivity and hence may contain unintended environmental biases. What is needed is an investigation into task group effectiveness, a study that would allow different task groups to be compared to one and other so that the merits of combining different combinations of platforms and capabilities could be quantified. Clearly, this is a question that is even more complicated than the issues that are being dealt with in this report. As such, it was an area of investigation that is beyond the scope of the current CMF 2015 Study and has been left to future efforts.

91. Another factor that pertains to this question of interpreting these results and was not considered in the FLEETSIM study but needs to be factored into any decision on fleet size is the whole question of attrition. Based on the results presented in this report one could argue that there is very little capability to weather the loss of even one CADRE or AOR platform without entailing serious degradation in AS(C) score performance. In the case of the CPFs, one would conclude that the loss of one or more of these platforms would have much less of an impact on the fleet's ability to meet its tasking requirements. Nonetheless, what level of attrition is expected or acceptable and what impact would such levels have on overall force structure responsiveness are two areas that have not been addressed by this study.

92. Finally, given the futuristic nature of this study and the rapid pace of technological change one may express surprise at the narrow focus of these results and argue that new technologies and advances in naval warfare will bring about sweeping changes over the time frame of this study. Three points relate to this admittedly valid concern. Firstly, in view of its 20-25 year perspective, this study did not consider that embarking on a speculative and futuristic technological forecasting effort was part of its mandate. These types of studies have been done in other forums and it was not our intention to repeat that work. Secondly, although the authors began with a considerable will to explore issues

which were 'outside of the box', the conservative approach that attends the long drawn out and expensive process of conceiving and concluding a major capital equipment replacement program lead us to the conclusion that: except in times of mobilization, changes to force structures tend to be small, evolutionary and incremental. Finally, notwithstanding the amazing technological times in which we live, the authors assumed that the technology, which would be seen over the next twenty years, would be evolutionary vice revolutionary in nature, would largely apply to the system vice platform level, and in the final analysis would not lead to a situation that would make the current types of maritime platforms obsolete.

93. In summary, FLEETSIM is a simulation tool that links national policy to force structure levels and capabilities. As such, it is a useful and valuable tool which lends itself to applications concerning a range of force structure, force generation and force employment questions. In terms of the results presented in this report, FLEETSIM shows us that there are a number of possible force structures that could continue to serve Canada's defence needs into the early part of the next century. These force structures bear further investigation.

V. CONCLUSIONS

94. The CMF 2015 Study has achieved two significant milestones: it has created a methodology and a model that can be used to study maritime force structure questions, and it has employed this model to gain some insight into the current and future force structure needs of the Canadian Forces.

95. In terms of model development and methodology, the authors conclude that:

- a) in the department's efforts to create an empirical and logical process that is able to link national policy directives to maritime force structure requirements, the development and employment of the FLEETSIM model is a significant achievement;
- b) the results from the use of the FLEETSIM model can show us which force structures would better serve Canada's defence needs in comparison to other force structures in a relative sense; and,
- c) the model's logic and data inputs are not at a sufficient level of refinement that would support a qualitative analysis of a given force structure's absolute or empirical level of responsiveness.

96. In terms of the results obtained from the study of a number of different force structures using FLEETSIM, the authors conclude that:

- a) AORs – force structures with less than three AORs are notably less responsive than force structures with three or more AORs;
- b) CADREs - force structures with zero or two CADREs are seriously affected in their abilities to respond to Scenario 2 or 5, and overall are notably less responsive than force structures with four or more CADREs;
- c) CPFs – a reduction in the number of CPFs by two has much less impact than the loss of two AORs or CADREs. Force structures with less than eight CPFs show a notable decline in responsiveness;
- d) Increasing the Capital Budget - spending significantly more money from the capital budget does not translate into a notable improvement in responsiveness; and,
- e) Decreasing the Capital Budget - spending significantly less money from the capital budget translates into notably poorer responsiveness;

VI. RECOMMENDATIONS

97. This report makes three main recommendations:

- a) the first is that, because FLEETSIM is a model which can accommodate all the force employment and force generation aspects of operating a maritime force, it should be considered for employment in future studies that may wish to explore a variety of maritime force management questions,
- b) the second recommendation follows the observation that allowing FLEETSIM to schedule normal readiness units for scenario taskings significantly improved a given force structure's responsiveness. This observation clearly merits further exploration; and,
- c) the third, and most important recommendation is that, the area which most warrants further investigation and resolution is the subjective nature of the grade tables. This could be addressed through the development of a more empirical and quantitative method of evaluating different task groups. One solution might be the development of a Task Group based simulation.

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FLEETSIM RULES FOR THE SCHEDULING OF MARITIME ASSETS

1. Early on in the model development stage, the rules of scheduling maritime assets to various activities were discussed. Both east and west coast scheduling staff were consulted. The information obtained from those discussions was collated and sent back to the coasts for comments. The results of this review and comments on the overall scheduling logic of FLEETSIM are presented below. Our main intention here is to reinforce the idea that FLEETSIM closely mimics the operations scheduling work done at the Formation level.

FLEETSIM LOGIC

2. This section will describe, concisely, the approach taken to generate taskings, and schedule assets to those taskings. The core of the simulation can be described in point form as follows:

Main Program (pseudo-code)

Initialise variables

Read in input data

Start Monte Carlo loop:

 Generate peacetime taskings

 Generate scenario taskings

 Schedule assets to the peacetime taskings

 Schedule assets to scenarios (in chronological order)

 Reschedule any 'bumped' taskings, if possible

 Collect measures of scheduling effectiveness

End Monte Carlo loop (exit after n times through the loop)

Output the aggregate measures of scheduling effectiveness

Stop

3. A description of FLEETSIM really amounts to a description of each process inside the Monte Carlo loop, and therefore we elaborate upon each process, in turn.

4. The scheduler must choose some tasking for which assets will be assigned. The tasking selected first gets first choice of schedule dates, whereas those taskings selected last run the risk of not getting the type or number of assets preferred for that tasking. We discuss the generation of taskings in the order of priority. Docking work periods (DWP - lengthy ship maintenance periods) are generated and scheduled first. We assign ready duty ships (RDS) last, and therefore there is a chance that the type of asset preferred for this role cannot be assigned, because it is already tasked, and some less-preferred asset must be assigned as RDS.

5. The order of priority is easily changed. Therefore, one should realise that some of the rules are FLEETSIM "idealizations" of the rules—often done to simplify the logic, yet still retain the general ideas discussed elsewhere in this annex.

GENERATE PEACETIME TASKINGS

DWP – Docking Work Period, or Refit

6. FLEETSIM begins by scheduling the DWP taskings. Each ship type must be assigned DWP time in the schedule, and so the expected amount of time in DWP (refit), and at high and normal readiness must be known. The table below provides this information. For example, we assumed a CPF would spend 2 years at High, 2 years at Normal, followed by 227 days in DWP. Here the 227 days in DWP is a maximum; the actual number of days spent is randomly generated so that there is between 170-186 days in maintenance, and 36-41 days spent doing post DWP trials. The data used to generate randomly the actual number of days spent in maintenance or post maintenance trials is obtained from the activity rate data set (Reference [11]).

7. To prevent many ships having the same readiness cycle, the start dates for each ship's cycle are staggered. This approach is perhaps idealized, but it minimises the chance that two CPF will be on DWP at the same time. There can still be overlap in the DWP, but the overlap is minimal.

8. Note from the readiness cycle that the aircraft are always at high readiness. That is, they have no maintenance period at all. The reason for this is that, as a simplifying

assumption, we have in effect taken out all the aircraft from the pool that would be either on major or periodic inspections. This was done for two reasons: namely because this was primarily a study focussed on the maritime surface and sub-surface assets, and because, in general, there are many more aircraft than there are ships thus making it easier to consider them as a pooled resource rather than on an individual basis.

TABLE A-1
READINESS STATE: THE NUMBER OF DAYS AT HR, NR, & ER FOR EACH PLATFORM

	Readiness State (in Days)		
Class	High	Normal	Refit
CPF	730	730	227
CADRE	1095	1095	451
AOR	1240	0	595
MRSV-Basic	1240	0	595
MRSV-Loaded	1240	0	595
MCDV	365	365	137
SSK	1400	0	425
Aircraft	365	0	0

Transfers Between Coasts

9. In some cases it is necessary to transfer assets between coasts. This occurs for example when there are three AORs, one on the west coast and the other two on the east coast (or vice versa). When the west coast AOR is on DWP, one of the AORs from the east coast is transferred westward. It is transferred back to the east coast when the resident AOR is out of its maintenance period. This logic applies to SSK, AOR, and the MRSV classes. The transfer is done only in the situation where there are three of one asset class and one platform is on a different coast from the others.

Standing Naval Force Atlantic

10. The Standing Naval Force Atlantic (SNFL) ship is either a frigate or CADRE class, chosen from either coast. Usually the east coast provides the ship, but every six deployments, the SNFL ship is taken from the west coast, if possible. Also, every five years it is Canada's turn to command SNFL, and a CADRE class ship is preferred. The program attempts to meet these 'policy' needs, but no penalty is paid if the preferred coast/asset cannot be obtained. These deployment parameters (i.e., 6 deployments, 5 years) can be changed. The duration of each mission was assumed to be 100-135 days, excluding transit time.

NATO

11. There may be other Nato tasks (e.g., Standing Naval Forces Mediterranean, MPA support to NATO) that are scheduled next. These missions are assumed to occur with random start date and duration, as per the input files.

Major Exercises

12. RIMPAC, MARCOT and other major exercises are scheduled next. These exercises have randomly determined duration (bounded by the input data for duration) but the start date is fixed within a period of time. For instance, a RIMPAC will usually begin on Julian day 140, give or take a month. RIMPAC exercises occur once every two years.

Short Work Period (SWP)

13. At this point all of the major taskings have been scheduled. Each ship from a given class now is provided with short work period maintenance. We have assumed, for example, that a CPF on the east coast will have 4 SWP per year, of duration 15-35 days. Ideally, the SWP are equally spaced in time, but previously scheduled tasks can prevent the scheduler from accomplishing this spacing. The amount of time that the scheduler permits the SWP task to be scheduled, before and after the ideal start date is provided in the input files. For example, for CPF SWP, the start date must lie within 45 days of the ideal. It is assumed that SNFL ships will be provided SWP "care" whilst in port, away from home.

Leave Task

14. Ships' companies are generally given four weeks leave in the summer and 2 weeks at Christmas. The program logic staggers the start dates for each ship class, for each leave period, in an attempt to ensure that there will always be a RDS available, and that there are still ships available to handle the lesser intensity scenario (Scenario 1) if it should arise.

15. As before, the SNFL type missions are handled somewhat differently—we assume that a SNFL ship (and its crew) will be able to take leave whilst in port, or during time in home port before or after the SNFL mission.

National Task

16. National Tasks include sovereignty patrols, and maritime support to RCMP and the Department of Fisheries. The input tables indicate the preferred types and quantities of maritime platforms that would be assigned to these tasks and one also would input information regarding the duration and frequency of these activities. The missions are randomly distributed throughout the year, except during leave periods.

Minor Exercise Task

17. Similar to National Tasks, the minor exercise missions are distributed throughout the year, except during leave periods.

Training Task

18. By training, in this context we mean training devoted to an outside agency such as a Fleet School course. The user will usually input information about each type of training, e.g., deep draft Navigation training, ORO training, and so on. These type of training are often provided at approximately the same time every year. With regards to aircraft related training, we have assumed that there will be a number of aircraft of each class used solely for training, and that these are not available for other peacetime or scenario missions. This is the same approach taken with regards to aircraft maintenance.

Trial Task

19. The trials missions are uniformly distributed throughout the year, except during leave periods.

Ready Duty Ship

20. Ready Duty Ships are scheduled in short contiguous periods through the entire schedule. The duration used was 4 days, i.e., each ship allocated to RDS status was scheduled in 4 day blocks.

GENERATE SCENARIO TASKINGS

21. All scenario missions are generated in the same manner. The number and duration of missions for each scenario is obtained probabilistically, using data from the input files. Then, the start dates for each of these missions are randomly generated. There is a maximum number of days that a task group is allowed to be away from home port. That value was set as 160 days. Therefore, any missions that are generated that are longer than 160 days must be split, i.e., two or more task groups are deployed. The follow-on task group is scheduled to depart home port so that there is a five day handover between TG at the scenario location.

SCHEDULE ASSETS TO THE PEACETIME TASKINGS

22. The numbers and types of assets to be selected for peacetime missions is taken from the Grade tables. The scheduler attempts to load A grade assets first; then, if this cannot be accomplished, the scheduler attempts to load B grade assets and so on.

23. There are some tasks like maintenance (i.e., DWP and SWP) and leave where all platforms of a given class are scheduled. In this case the logic is quite simple: for each ship, allocate time on this task at the previously generated start date. If that ship has already been scheduled on a higher priority task, then the program looks for another time period close to the preferred start date. One of the user inputs is the so-called "before" and "after" values.

For example, if before=7 and after=7, the program has roughly a two week period in which to place the start date of that task.

24. With the other types of tasks, such as major and minor exercises, and training, there is a more complicated procedure. The assets are selected on the basis of availability, readiness, previous usage, MH availability, and so on. For peacetime missions, the asset must not already be scheduled for some activity; if this is the case, the asset is not available for any other mission. That is, it cannot be bumped by some lower priority mission.

25. For all peacetime tasks, except SNFL, one must input the number of MH that are required. If that number of MH cannot be scheduled, then some other selection of assets (perhaps at a lower grade) must be scheduled. SNFL scheduling is a bit more complicated by the fact that the asset type rotates between CPF and CADRE. Therefore, the rule used is that if the number of available MH is less than the number required, there is a one grade reduction penalty for this mission. This is unlikely to happen for SNFL, since it has high priority in the scheduling procedure. Table A-2 provides the number of MH required for each ship class (with a hanger).

TABLE A-2
MAXIMUM NUMBER OF MH CARRIED BY EACH SHIP CLASS

Class	Max Number MH carried
CPF	1
CADRE	2
AOR	3
MRSV – Basic Configuration	
MRSV – Loaded configuration	

26. In the next table, we list the criteria involved in selecting assets for a given mission. For example, The program looks at the proportion of time that an asset has already been tasked in the previous year. A little used asset considered for a major exercise say, will be selected over another with higher usage, everything else being equal. The readiness state of the platform is another criterion of selection. Some readiness states are preferred over

others. In the Table A-3 below, read the symbol ">" as: "is preferred to", and ">>" would be read as: "is strongly preferred to". The letters H and N represent the High and Normal readiness states. As some ships may be nearing transition from High to Normal, we provide a HN readiness state as well. Looking at major exercises, we read the readiness criteria as: a high readiness ship is preferred to a high/normal readiness ship, which in turn is preferred to a normal readiness ship. The selection criteria for major exercises does not consider previous taskings to be a factor. The coast on which the asset is located is a factor however; a west coast major exercise will not include any east coast ships, for example.

27. The H10 and H30 codes represent task groups at High-10 day readiness and High-30 day readiness, respectively. Each coast shares the H10/H30 TG status for a period of six months. The status is switched between coasts every 180 days. Using the symbology defined above, we read H10>H30 as: an asset that is part of the H10 task group would be preferred to one that was at H30, i.e., on the other coast.

TABLE A-3
CRITERIA USED TO SELECTED THE ASSETS FOR MISSIONS

Task	Previous Usage	Readiness	Previous Mission	From Own Coast?	Can Draw From Other Coast?
Minor Exercise National (& OGD) Trials, Training, RDS	Less usage, more chance	H or N		YES	NO
Major Exercise, NATO-various roles	Less usage, more chance	H>HN>N		YES	NO
SNFL		H>(HN or N)	YES ¹	YES ²	YES ³
Scenario 1		H or N		YES	NO ⁴
Scenario 2		H>(HN,N)>R		YES	YES ⁵
Scenarios 3,4 & 5		H10>H30>(HN,N)>R		H10>H30	YES ⁶

SCHEDULE ASSETS TO SCENARIOS

28. We modified the original scheduling logic so that, at best, "C" grade assets would be selected for scenarios. The scheduler attempts to load C grade assets first; then, if this cannot be accomplished, the scheduler attempts to load D grade assets and so on. The intention here was to decrease the severity of the results.

¹ A ship just coming off a SNFL mission would be an highly unlikely candidate for another mission.

² There is a rotation schedule for selecting the SNFL ship from each coast.

³ There is a rotation schedule for selecting SNFL ship class type

⁴ Scenario 1: assets previously tasked are more likely to be bumped from low priority tasks; an asset with an available MH is more likely to be chosen over one that does not; an asset that is a RDS is likely to be chosen over one that is not; A SNFL ship is extremely unlikely to be chosen.

⁵ Scenario 2: assets previously tasked are more likely to be bumped from low priority tasks; an asset with an available MH is more likely to be chosen over one that does not; A SNFL ship is highly unlikely to be chosen.

⁶ Scenario 3,4,5: assets previously tasked are more likely to be bumped from low priority tasks; an asset with an available MH is more likely to be chosen over one that does not; A SNFL ship is unlikely to be chosen.

29. There is one main difference between the routine and scenario-specific scheduling logic. When the scheduler is scheduling routine tasks, it cannot bump assets off a previously scheduled task. Bumping is possible when the scheduler is attempting to find appropriate assets to send on a scenario. The scheduling of assets to scenarios is done in chronological order – scenarios that were generated to occur early in time are scheduled before the scenarios that start later in time.

30. When a scenario mission is generated, the first few days of that mission are called the scheduling “window of opportunity”. Scenario 1 was given a window of 2 days, while all the other scenarios were given 10 day windows. This is the amount of time that the Formation has to provide the assets that it has promised to be able to provide.

31. Each assigned asset has an “inaccessibility” rating for each day it is assigned. Thus, for example, a CPF on a RIMPAC exercise has an inaccessibility rating of 6 days. The higher the rating, the less available that asset is to be rescheduled on some more pressing mission. The ratings are provided as an input, and are easily changed. Some other inaccessibility ratings of interest are the DWP at 14 days, SWP at 6 days, and leave at 7 days. For example, at most it takes 7 days to recall sailors from leave.

32. If an asset that is already on a mission has an inaccessibility value that lies within the window, it can potentially be bumped off that mission; otherwise it is considered unavailable. For example, assume that a CPF has been scheduled to be on leave from Julian day 180-208 inclusive. On day 200 a scenario 1 arises. If the scenario was a low intensity scenario 1, then the inaccessibility (7) does not lie within the window [0,2], and the asset cannot be bumped off leave. If the scenario was a longer allowable reaction time, the inaccessibility value of (7) would lie within the window of opportunity [0,10], and the asset could be reassigned.

33. This availability logic is somewhat involved, and more intricate than what has been explained so far. For example, in the above example, the inaccessibility of the asset depends upon what particular day in the leave period was chosen. Near the end of the leave period, the inaccessibility decreases to zero by the last day of leave. If there must be a coast-to-coast transfer of assets, then a transfer time penalty must be paid. The transfer time penalty is measure of the time that it would take to transfer an asset from one coast to the other and, in the case of the naval units, assumes unrestricted access to the Panama canal and a high

speed of advance with few port stops. The inaccessibility increases by the amount of transfer time penalty, for each of the assets, as listed in the table below:

TABLE A-4
TIME TO TRANSFER EACH TYPE OF ASSET FROM COAST-TO-COAST

Asset	Transfer Time Penalty
	In days
CPF	9
CADRE	10
Supply Vessel	12
MCDV	12
SSK	12
HELICOPTER	4
MPA	1
F18	0

34. What this chart implies, is that under the current set of parameters, it would be possible to transfer any aircraft, frigate or destroyer to a scenario 2, 3, 4 or 5. The penalty here is used against a particular asset in the selection process, i.e., we may prefer to have an asset that is on the coast where the crisis has occurred, or on the coast where the H10 TG is situated. However, once the asset is selected, there is no penalty for having chosen that asset, even if it had to be transferred. It is assumed that the asset would join up with the rest of the group in due course. Note that only the faster aircraft such as F18 and MPA could be transferred to a low intensity national mission on the opposite coast (Scenario 1).

GRADING

35. The Task Based Grade Tables dictate the selection of assets and, therefore, the final grade for both routine tasks and scenarios. However, there can be deduction of that grade for scenarios in certain circumstances. We have already mentioned the deduction for lack of helicopters during scenarios. There can also be a deduction in the final grade if the selection of assets do not all have the appropriate readiness level. Scenario 1 does not require high

readiness ships (although they would be selected, if available). However, the higher intensity scenarios do require high readiness assets. There is an arbitrary deduction of one grade level for lack of readiness. That is, if any of the chosen assets are not at high readiness on the first day of the mission, the final grade for the mission drops one grade, e.g., a C grade becomes a D.

RESCHEDULE 'BUMPED' TASKINGS

36. As mentioned earlier, when the scheduler is attempting to find assets to be scheduled to a particular scenario, all the appropriate assets are scored. It may well occur that an asset must be bumped from a previously scheduled routine activity. If there is enough lead-time, the entire routine activity is rescheduled. In the case of an exercise, the time period stays the same and a revised set of assets would be selected. In the case of national tasks, surveillance missions, training and trials, the task would be cancelled, and rescheduled to a later time, that is, some time after the current scenario. The task could be relegated to a less-preferred set of assets, or under more extreme conditions, perhaps rescheduling is not possible. In either case, the grade assigned to the task would be lower than that originally assigned.

37. The SNFL tasking was given the highest priority in the scheduling process, and therefore the SNFL task is unlikely to be bumped unless there are no other appropriate assets to send instead. If a SNFL ship must be assigned to a scenario then the SNFL ship maintains its SNFL ship status, but is temporarily assigned to the scenario---it is double tasked in other words. This is realistic, for in the more intense multinational scenarios, it is possible that the SNFL task group itself could be involved.

Table B-1: Table of all 17 Force Structures

	CPF	CADRE	AOR	MRSV(b)	MRSV(I)	GEN AOR	MCDV	SSK	MH	MPA
0 CADRE 2 AOR	12			2		2	12	4	11	16
6 CPF 27 MCDV	6	4	2			2	27	4	11	16
6 CPF 2 CADRE	6	2	3			3	12	4	12	16
6 CPF 21 MCDV	6	4	3			3	21	4	13	16
8 CPF 2 AOR	8	4	2			2	12	4	20	16
8 CPF	8	4	3			3	12	4	20	16
0 CADRE	12		3			3	12	4	20	16
2 CADRE	12	2	3			3	12	4	20	16
10 CPF	10	4	3			3	12	4	20	16
2 AOR	12	4	2			2	12	4	15	16
3 CADRE 4 AOR	12	3		4		4	12	4	20	16
0 CADRE 5 MRSV(I)	12				5	5	12	4	20	16
BASELINE	12	4	3			3	12	4	20	16
2 CADRE 5 MRSV(I)	12	2			5	5	12	4	20	16
4 AOR	12	4	4			4	12	4	23	16
6 SSK	12	4		4		4	12	6	20	16
6 CADRE	12	6	3			3	12	4	20	16

NOTE 1: Based on ratios of current fleet of 18 + 3 a/c - five of which are in 2nd or 3rd line maintenance at any one time. The number of MPA in this table is the average number of MPA which are available on the flight line on any given day.

NOTE 2: Based on ratios of current Sea King fleet of 32 MH - 12 of which are in 2nd or 3rd line maintenance at any one time. The number of HS in this table is the average number of MH which are available on the flight line on any given day.

**AVERAGE SEA DAYS PER PLATFORM
FOR ALL 17 DIFFERENT FORCE STRUCTURES**

1. On the next page is a table of the Average Sea Days per platform for all 17 different force structures and normal demand. The 17 different force structures are listed down the left and side of the table and have been placed in the same order as they are presented in Figure 17: that is they are divided into four groups based on long term capital expenditure cost estimates and are ordered in terms of their ascending AS(C) score within these four groups.

Table C-1: AveSD Results for All 17 Force Structures

		CPF	CADRE	AOR	MCDV	SSK
0 CADRE 2 AOR	# of Hulls	12	0	2	12	4
	AveSD	100.9	0	64.3	49.8	58.4
6 CPF 27 MCDV	# of Hulls	6	4	2	27	4
	AveSD	126.7	99.1	63.7	28.7	62.8
6 CPF 2 CADRE	# of Hulls	6	2	3	12	4
	AveSD	134.7	124.4	56.2	55.5	66.8
6 CPF 21 MCDV	# of Hulls	6	4	3	21	4
	AveSD	127.8	99.7	61.1	36.4	67.9
8 CPF 2 AOR	# of Hulls	8	4	2	12	4
	AveSD	108.8	99.2	69.3	52.8	64.6
8 CPF	# of Hulls	8	4	3	12	4
	AveSD	114.3	101.9	66.5	55.5	71.6
0 CADRE	# of Hulls	12	0	3	12	4
	AveSD	104.2	0	60.9	52.4	61.7
2 CADRE	# of Hulls	12	2	3	12	4
	AveSD	95.1	124.4	67.2	54.8	72
10 CPF	# of Hulls	10	4	3	12	4
	AveSD	98.7	101.1	67.7	55.6	71.8
2 AOR	# of Hulls	12	4	2	12	4
	AveSD	84.9	98.9	73	51.5	67.5
3 CADRE 4 AOR	# of Hulls	12	3	4	12	4
	AveSD	90.7	110.8	54.2	55.2	74.2
0 CADRE 5 MRSV(I)	# of Hulls	12	0	5	12	4
	AveSD	105.9	0	42.4	56.5	69.7
BASELINE	# of Hulls	12	4	3	12	4
	AveSD	88.5	101	69.3	54.8	74.2
2 CADRE 5 MRSV(I)	# of Hulls	12	2	5	12	4
	AveSD	95.3	123	46.6	56.8	75.2
4 AOR	# of Hulls	12	4	4	12	4
	AveSD	88.8	101.1	55.9	55.6	75.6
6 SSK	# of Hulls	12	4	4	12	6
	AveSD	88.4	100.6	55.8	55.1	52.8
6 CADRE	# of Hulls	12	6	3	12	4
	AveSD	83.6	84.4	70.3	54.7	74.8

ALL 17 FORCE STRUCTURES
COMPLETE TABLES OF FLEETSIM RESULTS

1. On the next three pages are three tables of the FLEETSIM results for all seventeen of the force structures presented in this report. The 17 different force structures are listed down the left and side of the table and have been placed in the same order as they are presented in Figure 17: that is they are divided into four groups based on long term capital expenditure cost estimates and are ordered in terms of their ascending AS(C) score within these four groups. The results presented in these three tables are as follows:

- a. Table D-1 is the table of results for selection of high readiness units only for conditions of Normal Demand, Double Demand and Non-Overlapping Logic;
- b. Table D-2 is the table of results for selection of high and normal readiness units for conditions of Normal Demand, Double Demand and Non-Overlapping Logic; and,
- c. Table D-3 is the table of results of Average Sea Days per platform for Normal Demand, Double Demand and Non-Overlapping Logic for all 17 different force structures and normal demand.

Table D-1: Table of Results for 17 Force Structures Selected for HR

		ONLY HIGH READINESS						
		S ₁ P(C)	S ₂ P(C)	S ₃ P(C)	S ₄ P(C)	S ₅ P(C)	AS(C)-Score	AS(D)-Score
NORMAL DEMAND	0 CADRE, 2 AOR	0.699	0.000	0.378	0.395	0.000	0.294	0.184
	6 CPF, 27 MCDV	0.580	0.030	0.125	0.135	0.011	0.178	0.333
	6 CPF, 2 CADRE	0.574	0.035	0.165	0.171	0.006	0.190	0.485
	6 CPF, 21 MCDV	0.590	0.066	0.221	0.199	0.027	0.219	0.527
	8 CPF, 2 AOR	0.649	0.110	0.340	0.359	0.041	0.300	0.332
	8 CPF	0.669	0.183	0.508	0.544	0.123	0.405	0.419
	0 CADRE	0.731	0.000	0.649	0.651	0.000	0.406	0.101
	2 CADRE	0.707	0.271	0.515	0.513	0.294	0.460	0.343
	10 CPF	0.692	0.247	0.601	0.622	0.395	0.511	0.313
	2 AOR	0.702	0.361	0.465	0.478	0.151	0.431	0.286
	3 CADRE, 4 AOR	0.709	0.474	0.588	0.599	0.468	0.567	0.307
	0 CADRE, 5 MRSV(I)	0.712	0.668	0.639	0.632	0.302	0.591	0.345
	BASLINE	0.712	0.492	0.606	0.639	0.528	0.595	0.231
	2 CADRE, 5 MRSV(I)	0.704	0.711	0.532	0.554	0.421	0.585	0.324
	4 AOR	0.708	0.517	0.631	0.670	0.550	0.615	0.286
	6 SSK	0.791	0.489	0.653	0.645	0.529	0.621	0.252
	6 CADRE	0.701	0.613	0.702	0.663	0.622	0.680	0.181
DOUBLE DEMAND	0 CADRE, 2 AOR	0.628	0.000	0.292	0.276	0.000	0.239	0.153
	6 CPF, 27 MCDV	0.507	0.022	0.091	0.089	0.013	0.144	0.287
	6 CPF, 2 CADRE	0.505	0.018	0.115	0.114	0.007	0.152	0.373
	6 CPF, 21 MCDV	0.511	0.038	0.156	0.168	0.010	0.177	0.425
	8 CPF, 2 AOR	0.576	0.076	0.252	0.250	0.031	0.237	0.278
	8 CPF	0.606	0.142	0.415	0.389	0.100	0.330	0.365
	0 CADRE	0.672	0.000	0.476	0.474	0.000	0.324	0.129
	2 CADRE	0.653	0.204	0.392	0.392	0.215	0.371	0.311
	10 CPF	0.628	0.189	0.459	0.454	0.306	0.407	0.297
	2 AOR	0.629	0.231	0.348	0.353	0.108	0.334	0.246
	3 CADRE, 4 AOR	0.637	0.337	0.448	0.452	0.347	0.444	0.307
	0 CADRE, 5 MRSV(I)	0.635	0.528	0.495	0.499	0.228	0.477	0.370
	BASLINE	0.647	0.397	0.473	0.484	0.396	0.479	0.226
	2 CADRE, 5 MRSV(I)	0.633	0.605	0.422	0.429	0.336	0.485	0.335
	4 AOR	0.643	0.396	0.504	0.517	0.425	0.497	0.309
	6 SSK	0.738	0.391	0.497	0.483	0.408	0.503	0.257
	6 CADRE	0.651	0.476	0.557	0.530	0.435	0.530	0.181
NON OVERLAP	0 CADRE, 2 AOR	0.781	0.000	0.583	0.613	0.000	0.396	0.182
	6 CPF, 27 MCDV	0.660	0.042	0.244	0.305	0.145	0.279	0.413
	6 CPF, 2 CADRE	0.664	0.031	0.256	0.293	0.134	0.276	0.615
	6 CPF, 21 MCDV	0.665	0.077	0.342	0.373	0.173	0.326	0.615
	8 CPF, 2 AOR	0.716	0.122	0.511	0.579	0.317	0.449	0.382
	8 CPF	0.727	0.217	0.740	0.758	0.439	0.576	0.407
	0 CADRE	0.779	0.000	0.849	0.870	0.000	0.500	0.088
	2 CADRE	0.768	0.368	0.666	0.708	0.508	0.604	0.363
	10 CPF	0.748	0.335	0.815	0.826	0.680	0.681	0.301
	2 AOR	0.766	0.472	0.688	0.685	0.436	0.606	0.295
	3 CADRE, 4 AOR	0.766	0.574	0.765	0.738	0.674	0.704	0.278
	0 CADRE, 5 MRSV(I)	0.785	0.839	0.870	0.895	0.618	0.802	0.187
	BASLINE	0.766	0.660	0.832	0.830	0.809	0.779	0.203
	2 CADRE, 5 MRSV(I)	0.768	0.880	0.689	0.698	0.665	0.736	0.252
	4 AOR	0.769	0.680	0.813	0.850	0.794	0.781	0.205
	6 SSK	0.834	0.682	0.831	0.839	0.819	0.797	0.188
	6 CADRE	0.764	0.784	0.886	0.897	0.860	0.838	0.147

Table D-2: Table of Results for 17 Force Structures Selected for HR & NR

		HIGH READINESS & NORMAL READINESS						
		S ₁ P(C)	S ₂ P(C)	S ₃ P(C)	S ₄ P(C)	S ₅ P(C)	AS(C)-Score	AS(D)-Score
NORMAL DEMAND	0 CADRE, 2 AOR	0.699	0.000	0.623	0.646	0.000	0.394	0.099
	6 CPF, 27 MCDV	0.580	0.419	0.430	0.473	0.056	0.392	0.328
	6 CPF, 2 CADRE	0.574	0.628	0.711	0.713	0.440	0.613	0.161
	6 CPF, 21 MCDV	0.590	0.698	0.721	0.707	0.630	0.669	0.160
	8 CPF, 2 AOR	0.649	0.495	0.618	0.642	0.261	0.533	0.207
	8 CPF	0.669	0.813	0.798	0.794	0.788	0.772	0.076
	0 CADRE	0.731	0.000	0.808	0.805	0.000	0.489	0.054
	2 CADRE	0.707	0.708	0.811	0.809	0.598	0.726	0.099
	10 CPF	0.692	0.816	0.807	0.803	0.757	0.775	0.089
	2 AOR	0.702	0.557	0.644	0.649	0.335	0.577	0.183
	3 CADRE, 4 AOR	0.709	0.843	0.863	0.865	0.774	0.811	0.103
	0 CADRE, 5 MRSV(I)	0.712	0.922	0.950	0.939	0.923	0.889	0.063
	BASELINE	0.712	0.803	0.793	0.794	0.782	0.777	0.072
	2 CADRE, 5 MRSV(I)	0.704	0.918	0.871	0.907	0.852	0.850	0.095
	4 AOR	0.708	0.861	0.907	0.913	0.873	0.852	0.068
	6 SSK	0.791	0.837	0.841	0.844	0.782	0.819	0.095
	6 CADRE	0.701	0.826	0.807	0.796	0.806	0.787	0.075
DOUBLE DEMAND	0 CADRE, 2 AOR	0.628	0.000	0.470	0.453	0.000	0.310	0.103
	6 CPF, 27 MCDV	0.507	0.347	0.332	0.335	0.058	0.316	0.286
	6 CPF, 2 CADRE	0.505	0.467	0.502	0.515	0.306	0.459	0.173
	6 CPF, 21 MCDV	0.511	0.517	0.523	0.526	0.452	0.506	0.200
	8 CPF, 2 AOR	0.578	0.387	0.477	0.451	0.209	0.420	0.199
	8 CPF	0.606	0.678	0.661	0.628	0.614	0.637	0.098
	0 CADRE	0.672	0.000	0.889	0.886	0.000	0.409	0.067
	2 CADRE	0.653	0.580	0.669	0.666	0.470	0.608	0.111
	10 CPF	0.628	0.681	0.647	0.641	0.616	0.643	0.101
	2 AOR	0.629	0.418	0.485	0.481	0.243	0.451	0.175
	3 CADRE, 4 AOR	0.637	0.682	0.728	0.729	0.602	0.676	0.138
	0 CADRE, 5 MRSV(I)	0.635	0.840	0.852	0.850	0.795	0.794	0.086
	BASELINE	0.647	0.688	0.651	0.641	0.604	0.646	0.094
	2 CADRE, 5 MRSV(I)	0.633	0.841	0.791	0.782	0.717	0.753	0.127
	4 AOR	0.643	0.726	0.803	0.808	0.757	0.747	0.093
	6 SSK	0.738	0.735	0.689	0.670	0.620	0.690	0.140
	6 CADRE	0.651	0.693	0.654	0.628	0.599	0.645	0.097
NON OVERLAP	0 CADRE, 2 AOR	0.781	0.000	0.860	0.847	0.000	0.498	0.087
	6 CPF, 27 MCDV	0.680	0.595	0.655	0.677	0.341	0.586	0.317
	6 CPF, 2 CADRE	0.684	0.846	0.961	0.971	0.743	0.837	0.117
	6 CPF, 21 MCDV	0.665	0.926	0.954	0.965	0.886	0.879	0.106
	8 CPF, 2 AOR	0.716	0.663	0.868	0.869	0.557	0.734	0.179
	8 CPF	0.727	0.981	0.994	0.997	0.999	0.940	0.044
	0 CADRE	0.779	0.000	0.994	0.999	0.000	0.554	0.033
	2 CADRE	0.768	0.902	0.994	1.000	0.825	0.898	0.071
	10 CPF	0.748	0.972	0.991	1.000	0.993	0.941	0.042
	2 AOR	0.766	0.716	0.882	0.874	0.633	0.774	0.152
	3 CADRE, 4 AOR	0.766	0.970	0.994	1.000	0.977	0.941	0.041
	0 CADRE, 5 MRSV(I)	0.785	0.996	0.998	1.000	1.000	0.956	0.032
	BASELINE	0.766	0.975	0.991	1.000	0.994	0.945	0.038
	2 CADRE, 5 MRSV(I)	0.768	0.998	0.996	1.000	1.000	0.952	0.036
	4 AOR	0.769	0.990	0.993	1.000	1.000	0.950	0.037
	6 SSK	0.834	0.980	0.990	1.000	0.999	0.960	0.026
	6 CADRE	0.764	0.981	0.996	0.998	0.995	0.947	0.039

Table D-3: Table of Average Sea Day Results for 17 Force Structures

		AVERAGE SEA DAYS							
		CPF	CADRE	AOR	MRSVb	MRSVl	GEN AOR	MCDV	SSK
NORMAL DEMAND	0 CADRE, 2 AOR	100.9	0	0	64.3	0	64.3	49.8	58.4
	6 CPF, 27 MCDV	128.7	99.1	63.7	0	0	63.7	28.7	62.8
	6 CPF, 2 CADRE	134.7	124.4	56.2	0	0	56.2	55.5	66.8
	6 CPF, 21 MCDV	127.8	99.7	61.1	0	0	61.1	36.4	67.9
	8 CPF, 2 AOR	108.8	99.2	69.3	0	0	69.3	52.8	64.6
	8 CPF	114.3	101.9	66.5	0	0	66.5	55.5	71.6
	0 CADRE	104.2	0	60.9	0	0	60.9	52.4	61.7
	2 CADRE	95.1	124.4	67.2	0	0	67.2	54.8	72
	10 CPF	98.7	101.1	67.7	0	0	67.7	55.6	71.8
	2 AOR	84.9	98.9	73	0	0	73	51.5	67.5
	3 CADRE, 4 AOR	30.7	110.8	0	54.2	0	54.2	55.2	74.2
	0 CADRE, 5 MRSV(l)	105.9	0	0	0	42.4	42.4	56.5	69.7
	BASELINE	88.5	101	69.3	0	0	69.3	54.8	74.2
	2 CADRE, 5 MRSV(l)	95.3	123	0	0	46.6	46.6	56.8	75.2
	4 AOR	88.8	101.1	55.9	0	0	55.9	55.6	75.6
	6 SSK	88.4	100.6	0	55.8	0	55.8	55.1	52.8
	6 CADRE	83.6	84.4	70.3	0	0	70.3	54.7	74.8
DOUBLE DEMAND	0 CADRE, 2 AOR	114.1	0	0	87.3	0	87.3	57.9	71.9
	6 CPF, 27 MCDV	137.6	114.6	86.1	0	0	86.1	34.5	78.9
	6 CPF, 2 CADRE	146.8	143.9	75.6	0	0	75.6	68.5	86.9
	6 CPF, 21 MCDV	138.8	115.6	79	0	0	79	44.6	85.9
	8 CPF, 2 AOR	119.4	115.2	89.2	0	0	89.2	62	80.6
	8 CPF	125.2	119	83.5	0	0	83.5	66.8	89.6
	0 CADRE	117.5	0	79.5	0	0	79.5	61.1	78.9
	2 CADRE	106.2	144.2	84.1	0	0	84.1	64.7	88.5
	10 CPF	109.1	118.3	85	0	0	85	66.2	89.8
	2 AOR	94.5	116.7	93.3	0	0	93.3	60.7	82.4
	3 CADRE, 4 AOR	100.3	131.6	0	72.2	0	72.2	68.1	94.6
	0 CADRE, 5 MRSV(l)	119.9	0	0	0	58.3	58.3	69.9	91.5
	BASELINE	97.5	118.5	85.7	0	0	85.7	65.1	90.9
	2 CADRE, 5 MRSV(l)	105.6	141.7	0	0	61	61	69.4	95.8
	4 AOR	97.9	118.6	72.4	0	0	72.4	67.5	95
	6 SSK	97.6	118.7	0	73.2	0	73.2	67.6	69.1
	6 CADRE	92.4	98.2	86.2	0	0	86.2	64.2	91.2
NON OVERLAP	0 CADRE, 2 AOR	98	0	0	65.4	0	65.4	50.1	59.9
	6 CPF, 27 MCDV	123.6	96.2	64	0	0	64	28.6	63
	6 CPF, 2 CADRE	131	125.7	56.8	0	0	56.8	55.9	67.5
	6 CPF, 21 MCDV	125.1	98.1	61.9	0	0	61.9	36.6	69
	8 CPF, 2 AOR	105.7	96.6	69.9	0	0	69.9	52.7	65.2
	8 CPF	111.5	100.2	66	0	0	66	55.4	71.6
	0 CADRE	101.8	0	61.7	0	0	61.7	52.5	63.1
	2 CADRE	92.5	125.8	67.4	0	0	67.4	54.8	72.5
	10 CPF	96.7	99.6	68.5	0	0	68.5	55.7	72.8
	2 AOR	82.5	96.7	73.7	0	0	73.7	51.5	68
	3 CADRE, 4 AOR	89	110.6	0	53.2	0	53.2	54.4	73.9
	0 CADRE, 5 MRSV(l)	103.8	0	0	0	40.1	40.1	54.9	67.7
	BASELINE	86.5	98.8	68.5	0	0	68.5	54.4	73.9
	2 CADRE, 5 MRSV(l)	92.7	123.5	0	0	43.8	43.8	54.9	73
	4 AOR	87.1	99	53.6	0	0	53.6	54.1	73.9
	6 SSK	86.9	98.7	0	53.8	0	53.8	54	51.6
	6 CADRE	81.9	82.6	69.8	0	0	69.8	54.3	74.6

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3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C, or U) in parenthesis after the title) The Canadian Maritime Forces 2015 Study Phase II: Analysis of Maritime Force Structure Alternatives Using the FLEETSIM Model					
4. AUTHORS (Last name, first name, middle initial) MASSEL, LCdr P. L., BURTON, R.M.H., and MASON, D.W., MCLEAN, LCdr D.M., JESION, Dr. A.					
5. DATE OF PUBLICATION (month and year of publication of document) July 1999		<table border="1" style="width: 100%; border-collapse: collapse;"><tr><td style="width: 50%; padding: 5px;">6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.) 82</td><td style="width: 50%; padding: 5px;">6b. NO OF REFS (total cited in the document) 16</td></tr></table>		6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.) 82	6b. NO OF REFS (total cited in the document) 16
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7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual, or final. Give the inclusive dates when a specific report period is covered. ORD Report					
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10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document) ORD R9903		10b. OTHER DOCUMENT NOS. (Any other numbers under which the document was written) N/A			
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This report presents a description of the FLEETSIM model and a number of results which have been produced using this model to evaluate future maritime force structure options. The FLEETSIM model is a resource scheduling simulation model where different types of ships and aircraft are scheduled to perform a comprehensive selection of routine and unforeseen maritime force generation and force employment activities. This model was used to investigate the ability of different future maritime force structures to respond to Canada's national and international defence requirements. The results of this effort created an empirical and logical process that links national policy directives to maritime force structure requirements. Many possible force structures were examined and compared to the current (1998) Maritime force structure.

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- Canadian Maritime Forces 2015 Study
- FLEETSIM
- Canadian Task Group
- force structure
- force structure alternatives
- force structure analysis